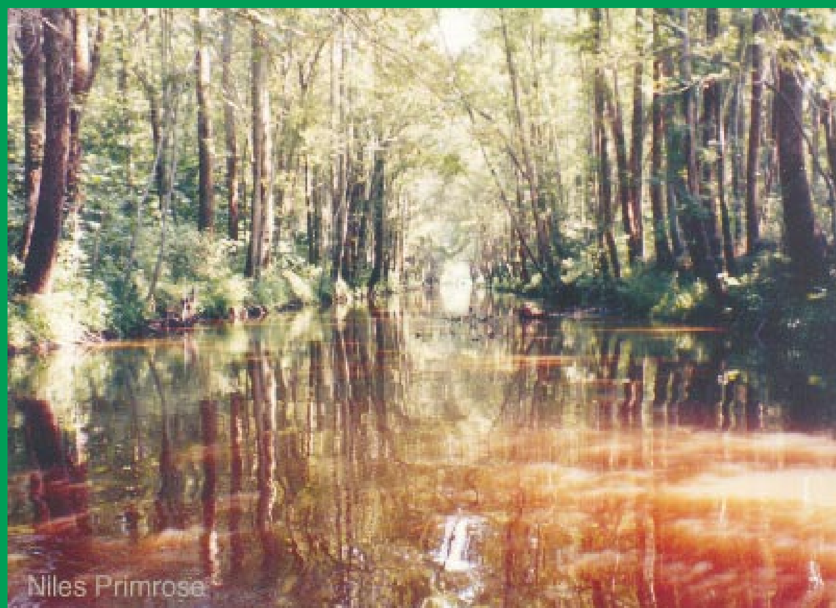
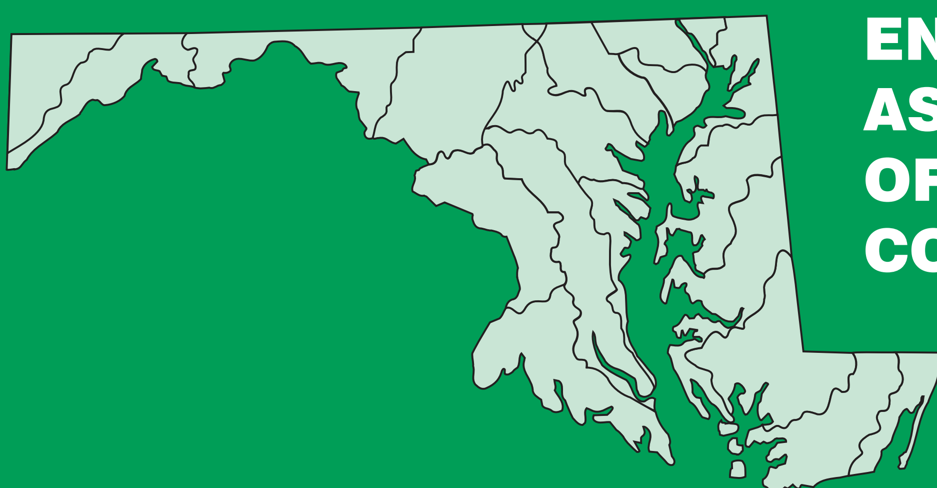
POCOMOKE

RIVER BASIN





ENVIRONMENTAL ASSESSMENT OF STREAM CONDITIONS

CHESAPEAKE BAY AND
WATERSHED PROGRAMS
MONITORING AND
NON-TIDAL ASSESSMENT
CBWP-MANTA-99-5

Parris N. Glendening
Governor

Kathleen K. Townsend
Lieutenant Governor

A message to Maryland's citizens

The Maryland Department of Natural Resources (DNR) seeks to preserve, protect and enhance the living resources of the state. Working in partnership with the citizens of Maryland, this worthwhile goal will become a reality. This publication provides information that will increase your understanding of how DNR strives to reach that goal through its many diverse programs.

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Maryland Department of Natural Resources
Tawes State Office Building
580 Taylor Avenue
Annapolis, Maryland 21401

Toll free number: 1-(877) 620 8DNR x8611
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POCOMOKE BASIN

ENVIRONMENTAL ASSESSMENT OF STREAM CONDITIONS

Ann Lenert
Christopher J. Millard
Paul F. Kazyak
Daniel M. Boward

December 1999

Maryland Department of Natural Resources
Resource Assessment Service
Monitoring and Non-Tidal Assessment Division
580 Taylor Avenue
Annapolis, MD 21401

Governor Parris N. Glendening

FOREWORD

The Maryland Department of Natural Resources (MDNR), Monitoring and Non-tidal Assessment Division prepared this report with financial assistance provided by the Coastal Zone Management Act of 1972, as amended, administered by the National Oceanic and Atmospheric Administration (NOAA). The report was funded in part by MDNR's Coastal Zone Management Program pursuant to NOAA Award No. NA67OZ0302. In addition to this report, basin reports are also being prepared for the Lower Susquehanna, Potomac Washington Metro, Ocean Coastal, and West Chesapeake basins.

Much of this report is based on results of the Maryland Biological Stream Survey (MBSS), a program funded primarily by the Power Plant Research Program and administered by the Maryland Department of Natural Resources. Field data for the Pocomoke basin were collected by the Maryland Department of Natural Resources. Analyses of water chemistry samples was conducted by the University of Maryland's Appalachian Laboratory (AL) under Contract No. MA97-001-003. Much of the initial data analysis for this report was conducted by Versar, Inc. under Contract No. PR-96-055-001\PRFP44 to MDNR's Power Plant Assessment Division.

This report helps fulfill two outcomes in MDNR's Strategic Plan: 1) A Vital and Life Sustaining Chesapeake Bay and Its Tributaries, and 2) Sustainable Populations of Living Resources and Healthy Ecosystems.

ACKNOWLEDGEMENTS

We are grateful to Bill Killen, Jay Kilian, Jeff Deberardinis, Timothy Parent, Jamie Mack, Ron Anderson, Mark Scott, for their work in the field. We are also grateful to Katie Meagher of AL for long hours and weekends spent in the laboratory to ensure that holding times and quality control measures were met for water samples. We thank Janis Chaillou and the Versar landowner permission crew for ensuring that permissions to sample streams on private property were obtained in a timely fashion. We also thank various MDNR staff: Marty Hurd, Anthony Prochaska, Derek Wiley, John Stavlas, and John Christmas for contributing to the document and providing Geographic Information Systems (GIS) support. We are also grateful to Dan Boward and Anthony Prochaska for editing; and Lamar Platt and Dung Nguyen for cover design and report layout.

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Maryland Biological Stream Survey

Executive Summary

This report describes existing aquatic resource conditions during 1997 in first, second, and third-order non-tidal streams in the Pocomoke River basin in Maryland. The report also begins to assess water quality and habitat problems in the basin, as well as defining areas of high ecological quality. This information may prove useful as watershed-specific strategies for restoring water quality in the Chesapeake Bay drainage are developed and refined.

The primary source of information for this report is the Maryland Biological Stream Survey (MBSS) conducted by Maryland Department of Natural Resources (MDNR) in 1997 to characterize Maryland streams, including those within the Pocomoke River basin. Although the primary focus of the MBSS is on acid deposition impacts, the survey is also being used for other purposes such as reporting on watershed conditions. The MBSS is a statewide survey of first, second, and third-order non-tidal streams designed to characterize current biological and habitat conditions and provide a basis for assessing future trends. The probabilistic design used for the survey, in which all streams have a known probability of being sampled, allows for quantitative estimates of stream characteristics and conditions. This approach is not unlike taking a random sample of voters to determine who is likely to win an election.

FINDINGS

Water Quality

About 29% of the stream miles in the basin had summer dissolved oxygen levels lower than the state water quality criterion of 5.0 mg/L. This suggests that excessive loading of oxygen-demanding organic chemicals is a problem in many Pocomoke basin streams.

Fourteen percent of the stream miles in the basin had acid neutralizing capacity (ANC) less than 0 μeq/L, and thus were chronically acidified. About 52% of the stream miles in the basin had ANC levels between 0 μeq/L and 200 μeq/L and are susceptible to episodic, storm-related acidification. The remaining 34% of the stream miles had ANC levels greater than 200 μeq/L and are considered well-buffered and relatively immune to acid deposition impacts.

Acidity is a water quality problem in Pocomoke basin streams. Almost two-thirds (62%) of the stream miles had a springtime pH less than 6, the level below which significant adverse impacts on aquatic life are known to occur. Summer pH values were above 6 for 73% of the stream miles, possibly influenced by both seasonal flow changes and algae growth.

Elevated nitrogen levels (nitrate-nitrogen greater than 1 mg/L) occurred at 60% of the stream miles in the basin. The primary sources of nitrates appear to be agriculture, but urban runoff and acid deposition are also likely contributors.

Physical Habitat

Almost two-thirds (62%) of the stream miles were rated Poor or Very Poor for instream habitat. The causes of degraded habitat include loss of woody debris, channelization, sedimentation, and riparian zone deforestation.

About 79% of the stream miles in the basin were channelized (over 40% altered banks or recent bar formations), reducing the ability of the streams to retain and process nutrients and provide diverse habitat for biota.

Under one-quarter (23%) of the stream miles had unstable stream banks. In contrast, 26% of the stream miles had highly stable banks. Eroding stream banks degrade available habitat and may be an important source of sediment and nutrients to Chesapeake Bay.

In general, riparian zones along streams in the basin were in fairly poor condition. Roughly one-fourth (22%) of all stream miles had unvegetated riparian zones while an equal number of stream miles had buffers greater than 50 meters wide. Second-order streams, with the most common adjacent land use being croplands, were the least shaded by the riparian buffer vegetation.

Fish

A total of 36 fish species were collected in the basin, including two gamefish species: largemouth bass and chain pickerel. Largemouth bass were the most abundant gamefish collected, with an estimated basin population of one thousand fish.

About 2.9 million fish live in non-tidal streams in the basin. The most abundant fish species was the Eastern mudminnow, a pollution-tolerant species, estimated at more than 1.5 million individuals.

Based on MDNR's Index of Biotic Integrity (IBI) for fish, 21% of the stream miles in the basin were in Good condition, while 18% were in Poor condition. The remaining stream miles (61%) were assessed as Fair. No stream miles were rated Very Poor.

Benthic Macroinvertebrates

Based on MDNR's benthic macroinvertebrate IBI, almost two-thirds (62%) of all stream miles in the basin were assessed as Poor or Very Poor. Three percent of the stream miles were assessed as Good.

About one-third (110) of the 346 stream-dwelling benthic macroinvertebrate genera found in Maryland were collected in the basin. Dominant types include midges, isopods, and blackfly larvae.

Reptiles and Amphibians

Reptiles and amphibians were present at 89% of the sites sampled. A total of 12 species of frogs, toads, turtles, salamanders, and snakes were collected.

Summary

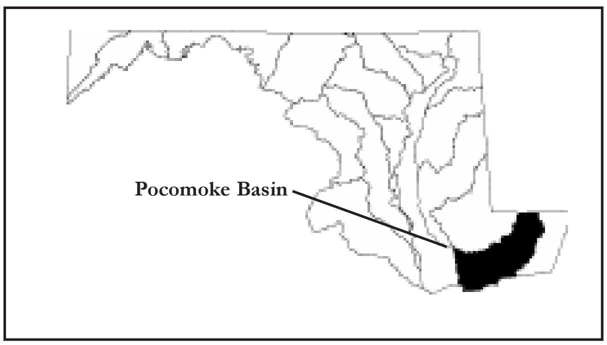
The major impacts to non-tidal streams in the basin appear to be nitrogen enrichment, acidification, stream channelization, and lack of functional riparian buffers. The acidic conditions are natural for low-flow, high organic content "blackwater" streams. The most likely reasons for the remaining impacts are stream alterations resulting from agricultural activities.

Introduction

Chapter 1 One

PURPOSE OF THIS REPORT

This report describes aquatic resource conditions in first, second, and third-order non-tidal streams in the Pocomoke basin in Maryland during 1997. The report also begins to identify water quality and habitat problems in the basin, along with areas of high ecological value. We hope that this information will prove useful as specific strategies for restoring water quality in Chesapeake Bay and its tributaries are developed and refined.



The Pocomoke basin, one of Maryland's 18 major river basins, lies in the southeastern part of the state and includes parts of Wicomico, Somerset, and Worcester counties.

STREAM RESOURCES

The flowing waters of Maryland represent a vital lifeblood to its residents. In addition to providing a source of drinking water and water for agricultural and industrial uses, Maryland's streams and rivers offer recreational opportunities, attract tourists, and support commercially and recreationally important fish and shellfish. Forested riparian zones contain some of the richest and most diverse plant and animal communities in the state. These areas help temper the effects of heavy rainfall and storm water runoff, shade the stream channel, increase bank stability, and contribute leaf litter and woody debris--sources of food and habitat for stream biota. In many cases, the aesthetic attraction of streams and rivers has served as a catalyst for economic development. Nearly all of the flowing waters in Maryland, including those within the Pocomoke basin, drain to Chesapeake Bay — therefore the quality of these systems has a direct impact on the health of the Bay. As most Marylanders know, Chesapeake Bay is one of Maryland's most important economic and natural resources.

Despite these values, Maryland's streams and rivers have been abused and neglected, often converted to flood routing systems or used as drains for unwanted wastes. Increasingly, Marylanders are realizing that our mistreatment of natural resources is neither economically nor environmentally sustainable. Efforts are underway to restore degraded systems and to protect those that are healthy. In the end, the success of these efforts will be determined by how much we cherish these most valuable natural gifts.

INFORMATION SOURCES

The primary data source for this report is the 1997 Maryland Biological Stream Survey (MBSS) conducted by the Maryland Department of Natural Resources (MDNR). Where appropriate, 1994 MBSS data have been used to supplement information regarding fish and herpetofauna distributions. The MBSS is a statewide survey of first, second, and third-order streams designed to characterize current biological and habitat conditions and provide a basis for assessing future trends. The probabilistic design (all streams have a known probability of being sampled and sites are randomly selected) used for the survey allows unbiased estimates of stream characteristics and conditions. For example, the abundance of a given fish species in an entire basin can be validly estimated using the MBSS design. Because first, second, and third-order streams represent approximately 99% of the non-tidal stream miles in the Pocomoke basin, MBSS results should accurately represent stream quality. Examination of conditions in small streams also helps to identify specific problem areas where local protection, enhancement, and restoration efforts should be focused.

To provide a comparison of past and present conditions, historical information is presented where appropriate and available. In addition, information on land use, hydrology, and other aspects of the basin is also provided so that the conditions observed in streams can be placed in context of human activity.

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Basin Description

Chapter Two 2

This chapter uses existing information to provide an overview of the Pocomoke basin including ecological, recreational, and economic resources. This provides a context for interpreting the assessment of stream conditions found in Chapter 4.

HISTORY

At the time European settlers first arrived in Maryland in the early 1600s, the Pocomoke basin was believed to have the largest Native American population in the state. To a large extent Native American life-styles had negligible environmental impacts, however as European colonization proceeded, natural resources were increasingly depleted for activities such as shipbuilding, brick manufacturing, iron smelting, and tobacco farming. Over time, many of the forested and wetland areas of the basin were logged, drained, or cultivated to support agriculture. This alteration was, and continues to be, most pronounced in the upper part of the basin.

The four largest urban areas in the basin are Snow Hill and Pocomoke City along the Pocomoke River, Princess Anne by the upper Manokin River, and Crisfield, near the mouth of the Little Annemessex River. All four towns were settled during the mid to late-1600s and relied on the rivers and bays for food, trade, and transport. Rail lines to Crisfield and Snow Hill enhanced these towns' agricultural and seafood industries. The increased demand for farm products brought a corresponding increase in population, causing Somerset county to be divided in 1742. Princess Anne was named the official county seat for Somerset County, and Snow Hill became the county seat of the newly formed Worcester County.

As a result of increasing development within the basin, stream and river channels underwent large-scale modification. From the 1700s until the early 1900s, ships, barges, and boats regularly used the Pocomoke River for transportation and trade. To facilitate navigation, the mainstem of the Pocomoke River was channelized and deepened from 1912 to 1947 (Ballard 1982). However, channelization of streams in the basin extended over a much longer period of time, as this practice was initiated during the 1600s for farming and transport purposes and is still occurring today.

BASIN CHARACTERISTICS

The Pocomoke basin drains approximately 639 square miles in Wicomico, Worcester, and Somerset counties in Maryland (MOP 1994), as well as portions of Sussex County in Delaware, and part of Accomack County in Virginia. This includes the Pocomoke River, Dividing Creek, Nassawango Creek, Big Annemessex River, and Manokin River. The Pocomoke River mainstem flows 49 miles in Maryland before reaching Pocomoke Sound. The lower portions of this system, and other tributaries, are brackish and the surrounding land is primarily tidal marsh. The freshwater portion of the Pocomoke River begins at the mouth of Nassawango Creek, north of Snow Hill.

There are a total of 271 miles of first, second, and third-order non-tidal streams in the Maryland portion of the basin. First-order streams make up 81% of the stream miles, while second and third-order streams constitute nearly 19% of the total (Roth et al. 1999). Forth-order and larger freshwater streams account for less than 1% of the non-tidal streams in the basin. The basin lies entirely within the Coastal Plain physiographic province.

Climate exerts a major influence on basin water quality, as it affects the water budget and precipitation chemistry. The quantity and chemical composition of the water added through precipitation, coupled with the regions underlying geology dictate the chemical and biological features of the basin. The climate in the Pocomoke basin is generally humid and temperate, with an mean annual temperature of 57° F. Temperature ranges from an average daily maximum of 86° F to an average minimum of 25° F. Mean annual precipitation from 1960 to 1990, was 44 inches (RESI 1998).

The basin's topography is relatively flat. At a maximum elevation of 85 feet above sea level, it has one of the lowest elevations of any basin in the state. The soils of the area originate from parent material of unconsolidated deposits of clay, silt, sand, gravel, and shell which were part of an expansive delta formed by the ancient Susquehanna River. Because of the low topographic relief and proximity to sea level, soils in the basin are subject to periodic flooding. A wide variety of soil conditions exist, from saltwater marshes and poorly drained mucks and silty loams, to slightly better drained sandy loams past the tidal reaches of the river. All of the soils are acidic and require extensive drainage and the addition of soil amendments for agricultural use. The poor drainage of the soils combined with a relatively high water table also impose limits on the suitability of the land for residential purposes (USDA 1966, 1970).

Forested areas of the basin are dominated by loblolly pine interspersed with basket oak, willow oak, red maple, sweet gum, American holly, and black gum (Brush et al. 1977). The area near Crisfield is predominantly loblolly pine and wax myrtle. Bald cypress, with green ash, red maple, and sweet gum are common along the banks of the Pocomoke River and Nassawango Creek. Willow oak, chestnut oak, post oak, and blackjack oak can be found near Snow Hill. River birch, sycamore, slippery elm, green ash, red maple, tulip poplar, and black gum line the upper reaches of the Manokin River and Dividing Creek.

In the 1950s and 1960s, several government agencies advocated the planting of a non-native shrub called multiflora rose as a means to enhance wildlife habitat on farms and in backyards. Since then, this species has spread into every drainage basin in the state and it continues to spread today. As a result, this introduced species now constitutes a significant threat to efforts to restore lost native vegetation along streams. Multiflora rose is an opportunistic plant that colonizes cleared areas such as timber cuts and pastures— often so completely that virtually no other plants can compete with it. Because aquatic insects have adapted over thousands of years to feed on leaves fallen from native trees and shrubs, the takeover by multiflora rose is reducing the amount of food available for them. This, in turn, has very likely led to impacts on our native fish communities which depend on insects to survive. An additional problem is that unlike mature trees whose root systems typically extend below the water level of a stream, the roots of multiflora rose do not protect the lower stream bank where erosion is

Multiflora rose (*Rosa multiflora*)

most severe. Like many other introductions of non-native species, the introduction of multiflora rose has resulted in unforeseen negative consequences— today, many riparian areas in the basin are virtually impenetrable because of the success of this noxious species.

LAND USE AND HUMAN POPULATION

Nearly 70 percent of the Pocomoke basin is forested or agricultural land (MDNR 1997a; Figures 1 and 2). These land uses have had the greatest influence on the basin as forested areas have been repeatedly logged over the past 300 years and expansive agricultural areas have been developed for poultry and livestock operations. Open water covers approximately 21% and the remaining land uses, wetland and urban, comprise 8 and 2 percent of the basin, respectively. Wetlands in the basin are most extensive in tidal areas, but include non-tidal areas in the upper basin as well.

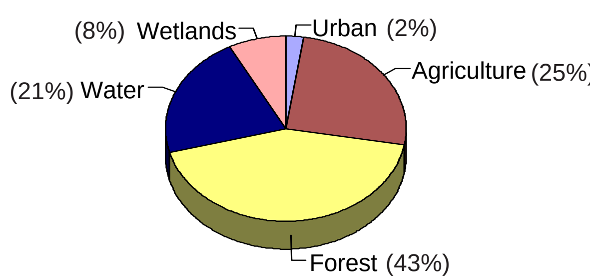

Figure 1. Land use classifications in the Pocomoke basin (MDNR 1997a).

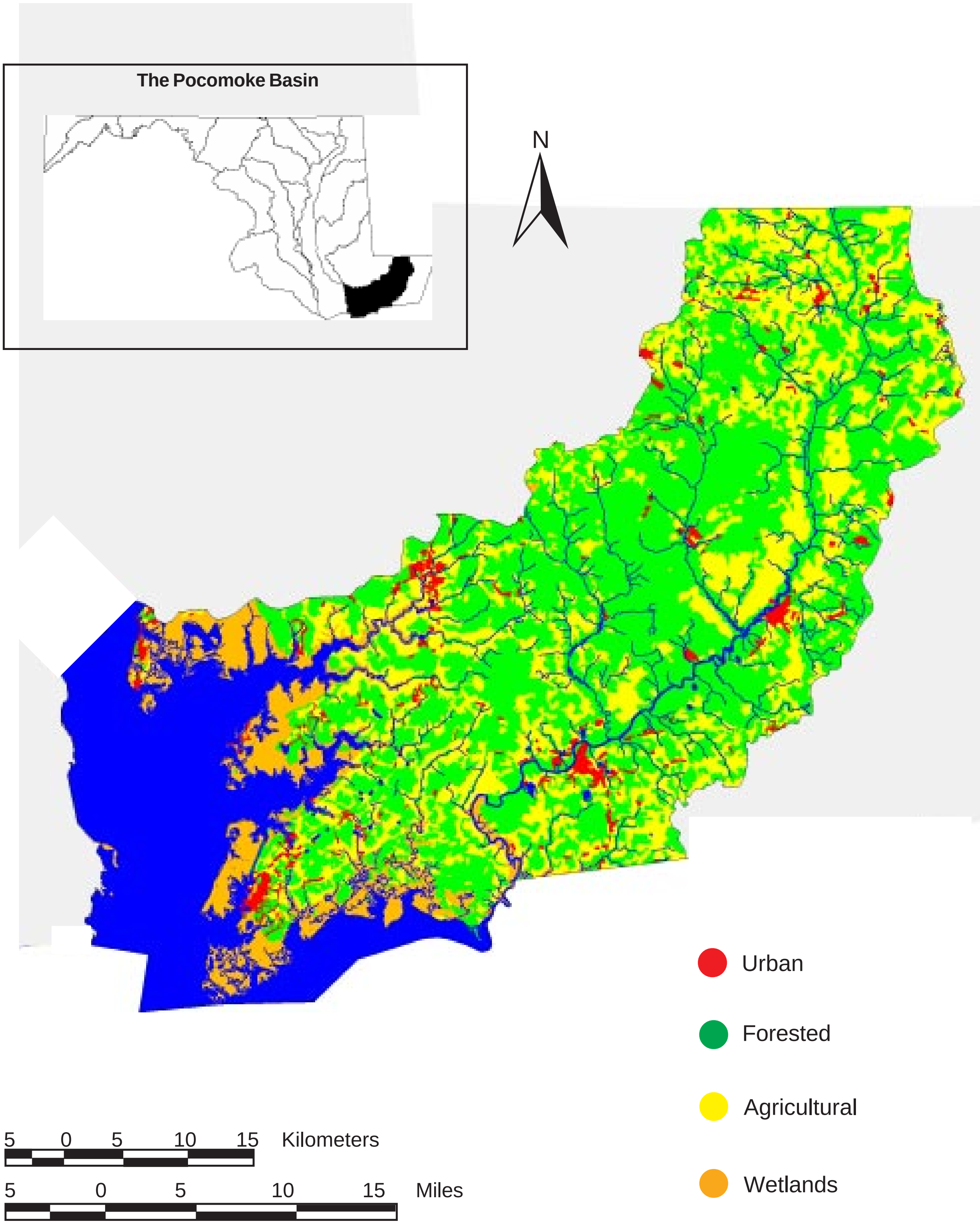

Figure 2. Land use in the Pocomoke Basin (MOP 1994).

Based on 1990 census data, (MDNR 1997a) about 60,000 people live in the basin, with nearly 20% of the population clustered around Snow Hill, Pocomoke City, Princess Anne, and Crisfield. Despite being one of the more rural and least densely populated basins in the state (36 persons/km^2) the region's population is increasing and is projected to grow about 25% to roughly 75,000 people by 2020.

WATER QUALITY

The Maryland Department of the Environment (MDE) classifies all surface waters in Maryland by their "designated use" (COMAR 1997). All waters of the state receive at least a Use I designation; that is, they are protected for contact recreation, fishing, and protection of aquatic life and wildlife. Use II waters are suitable for shellfish harvesting, while Uses III and IV are designated as natural and recreational trout waters, respectively. Additional designations are made for waters recognized for their function as drinking water supplies.

Within the Pocomoke basin, surface waters were classified as Use I and Use II (COMAR 1997; MDNR 1996). Elevated bacterial and nutrient levels were primarily due to agricultural runoff, with localized problems from urban runoff, failing septic systems, and/or improperly treated domestic or industrial wastewater in the more highly developed areas.

Because of the extensive amount of wetland drainage and the naturally acidic soils in the basin, pH levels in most streams are naturally low. The capacity of streams to buffer acids and maintain water quality sufficient to sustain sensitive aquatic species has been, and continues to be, reduced by atmospheric deposition. Based on sampling conducted as part of a statewide stream chemistry survey in 1987, more than 50% of the streams in the basin had pH levels less than 5 and were either acidified or susceptible to acidification from atmospheric deposition (MDNR 1988).

RESOURCE VALUES

Recreational Resources

The basin has numerous parks, forests, and recreational areas that offer fishing, hunting, trapping, canoeing, picnicking, camping, swimming, hiking, boating, nature studies, and off-road vehicle trails. There are several State Parks and Natural Resource Management Areas, including: Pocomoke River State Forest, Pocomoke State Park, Janes Island State Park, Milburn Landing, and Shad Landing (Ballard 1982). There are also several Wildlife Management Areas. These include Pocomoke River, Pocomoke Sound, Cedar Island, and Wellington Wildlife Management Areas.

Ecological Resources

The Pocomoke basin is a "black water" system because of its tea-colored water. Tannins leaching from tree leaves and decomposing wetland plants stain the water dark. The basin contains unique and extensive acreage of cypress and cedar swamps that harbor fauna and flora not usually seen in Maryland. It has been described by ornithologists as having one of the best environments for bird life on the Atlantic Coast. In 1971, the Maryland legislature recognized these unique qualities and designated the Pocomoke a Scenic River (Ballard 1982).

There are roughly 2,700 acres of land that are considered exceptional ecological resources by the Maryland Natural Heritage Program, earning a Type Two State Wildlands classification (Ballard 1982). This area along the Pocomoke River mainstem includes the state-owned Cypress Swamp and Pocomoke State Forest. In recognition of this title, the Maryland Office of Planning has classified the river as an area of critical concern (Ballard 1982). The purpose of this classification is to ensure that future uses of the River do not detract from the quality of the natural resources in the basin.

Wetlands are a rich ecosystem for fish and wildlife. The basin's wetlands provide spawning and nursery habitat for anadromous fish species, such as alewife and blueback herring, as well as gamefish (bass, sunfish, crappie, and bluegill). These areas are also important for migratory birds along the Atlantic fly-way.

Extractable and Renewable Resources

The basin contains few mineral deposits of commercial value. Sand and gravel are extracted from several areas, these materials are primarily used for local highway construction and maintenance. Timber resources are dominated by softwoods, particularly loblolly shortleaf pine. Hardwoods are harvested in lesser amounts and are primarily comprised of sweet gum, white oak, red oak, and some soft maples (Frieswyk and DiGiovanni 1988).

Fishery Resources

Recreational fishing is economically important in the Pocomoke basin. An estimated 40,000 angler-days are spent fishing in the freshwater areas of the basin each year. Species sought by anglers include anadromous blueback herring and alewife, semi-anadromous white perch and yellow perch, and resident largemouth bass and black crappie. American shad, an historically important anadromous species, has declined precipitously during the last two decades throughout the Chesapeake Bay drainage and have not yet recovered. Although not as pronounced, both blueback herring and alewife declined in abundance during the same period.

CITIZEN INVOLVEMENT

During the last decade, an increasing number of concerned citizens have become involved in organizations and programs working to protect and restore Maryland's aquatic resources. Many such organizations focus their work on a particular watershed and take part in monitoring activities, community outreach, and preservation issues. The following lists some of the groups that are active in the Pocomoke basin.

Alliance for the Chesapeake Bay (ACB)
6600 York Rd.
Baltimore, MD 21212

Audubon Naturalist Society
8940 Jones Mill Road
Chevy Chase, MD 20815

Chesapeake Bay Foundation
162 Prince Georges Street
Annapolis, MD 21401

Chesapeake and Coastal Creeks Coalition
P.O. Box 206
Maryland Line, MD 21105-0206

Maryland Save Our Streams
258 Scotts Manor Drive
Glen Burnie, MD 21061

Nassawango Creek Preserve, Stewardship Committee
Creek Point Farm, 3532 Tall Pines Lane
Snow Hill, MD 21863

Nature Conservancy - Maryland Chapter
P.O. Box 4051, 110 N. Division Street
Salisbury, MD 21803

...or check out the U.S. Environmental Agency's website, ***Surf Your Watershed***, at http://www.epa.gov/surf/

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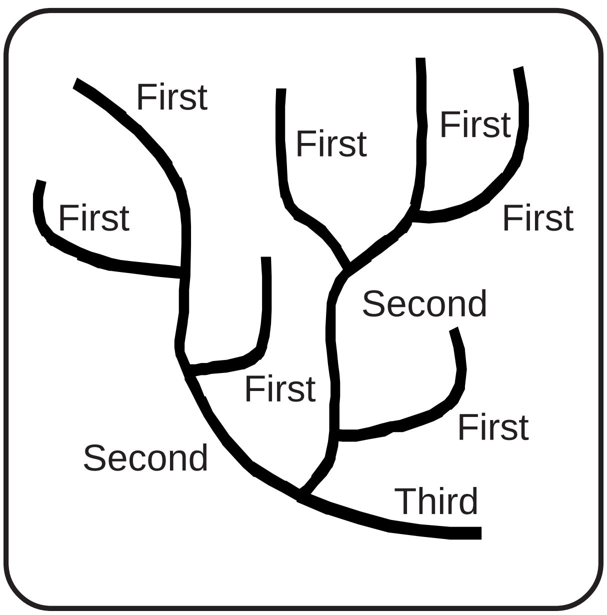
Maryland Biological Stream Survey

Survey Design and Methods

Chapter Three 3

This chapter briefly outlines the approach used by the MBSS to assess stream resources of the Pocomoke basin. The sampling design used for this assessment differs from other stream surveys that have been conducted in Maryland. Randomly selected sampling sites on first, second, and third-order non-tidal streams (Strahler 1964) were chosen by computer rather than selected by the investigator. This approach allows estimates to be calculated for an array of ecological factors such as fish density and stream habitat condition. Non-randomly selected sites were also sampled to provide additional information on fish distributions. Figure 3 shows the location of random and non-random sites sampled during the 1994 and 1997 MBSS.



STREAM ORDER

Stream order is a simple way to measure stream size. The smallest permanently flowing stream is termed first-order, and the union of two first-order streams creates a second-order stream. A third-order stream is formed where two-second order streams join. Stream order is directly related to watershed area.

After landowner permissions were obtained, sample sites were located with Global Positioning System (GPS) receivers, fish and benthic macroinvertebrates were collected, and physical habitat features were evaluated using methods patterned after EPA's Rapid Bioassessment Protocols (Plafkin et al. 1989). Reptiles, amphibians, and mussels were also surveyed on a presence/absence basis. Water quality was sampled using protocols previously established for acid rain studies in Maryland (MDNR 1988). Because the initial purpose of the MBSS was to assess the effect of acid rain on Maryland streams and rivers, other important water quality measures such as phosphorous and turbidity were not measured.

Because most stream sites in the Pocomoke basin were on private land, landowner permissions were sought for each randomly selected site. This procedure required contact with property owners, usually by phone. Overall, 94% of the landowners contacted in the basin gave DNR permission to have streams on their property sampled by the MBSS.

All catchments draining to the MBSS sampling sites were delineated and land use (MOP 1994) was estimated for each. Throughout all sampling and data management activities, an extensive Quality Control program was employed. Additional technical information about the methods used to survey streams and survey results can be found in Appendices A through D of this report, in Roth et al. (1999), and in Kazyak (1996).

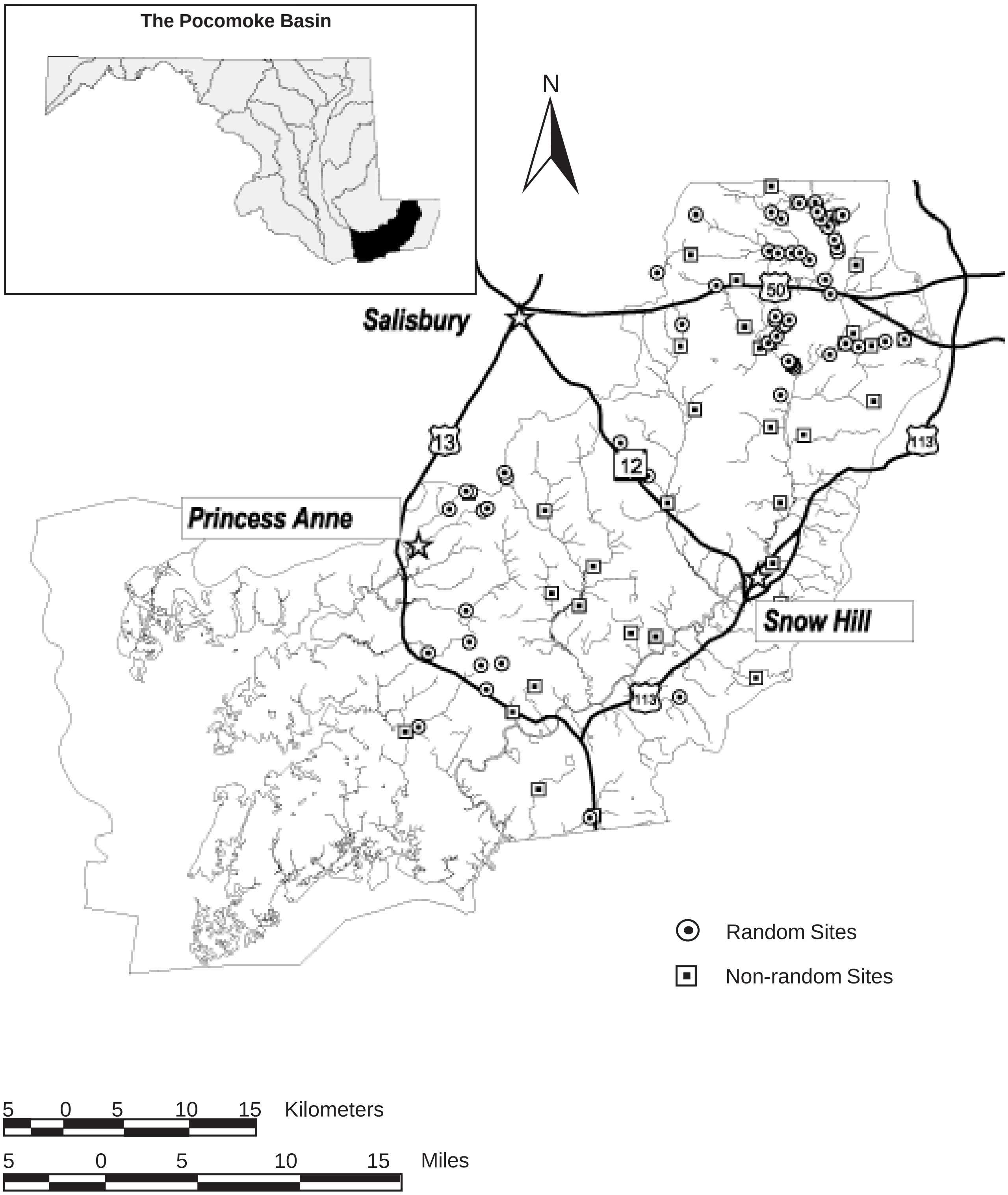


Figure 3. Location of 1994 and 1997 sites in the Pocomoke basin. Major highways, population centers, and other features are shown for reference.

Maryland Biological Stream Survey

Current Status of Aquatic Resources

Chapter Four 4

This chapter uses 1997 MBSS data from 28 randomly selected (quantitative) sampling sites to describe the current status of non-tidal streams in the Pocomoke basin. Where appropriate, 1994 and 1997 data have been used from random and non-random (qualitative) sites to supplement information regarding fish and herpetofauna distributions. A map of these sites is shown in Figure 3, and a list of streams sampled in 1997 is presented in Appendix B.

GENERAL CHARACTERISTICS OF THE POCOMOKE BASIN

All sampling sites were located in the Coastal Plain physiographic province, where streams tend to be gently sloping with few riffles to aerate the water. Of the twenty-eight sites sampled in 1997, nine were first-order streams, six were second-order, and the remaining thirteen were third-order. Stream gradient ranged from 0.10% to 0.30%. Wetted width varied from 0 meters (for intermittent damp or dry sections of sampled streams) to 15 meters, with an average width of 7 meters. Mean maximum depth was 0.64 meters and ranged from 0.10 to 2 meters.

WATER QUALITY

During the spring index period, whole water grab samples were collected at each site for laboratory analysis of pH, acid neutralizing capacity (ANC), conductivity, sulfate, nitrate-nitrogen, and dissolved organic carbon (DOC). Summer index period sampling included *in situ* measurements of dissolved oxygen (DO), pH, temperature, and conductivity at each site to further characterize water quality conditions. Water chemistry data from the 1997 quantitative sites are presented in Appendix C.

Dissolved Oxygen

Nearly one-third (29%) of the stream miles in the basin had summer dissolved oxygen values below the state water quality criterion of 5.0 mg/L (COMAR 1997). Four sites, Forest Grove Branch, Campbell Ditch, Jones Ditch, and Millville Creek, fell into this category with a mean concentration of 2.35 mg/L. Over all sites, dissolved oxygen concentrations averaged 6.3 mg/L. However, it should be noted that these data only reflect first through third-order streams and do not take into account larger tributaries where DO problems are common.

> Dissolved oxygen (DO) is one of the most basic requirements of aquatic organisms, thus DO levels play an important role in shaping biological communities in streams. DO in streams may be low due to nutrient-rich runoff and groundwater inputs from urban and agricultural areas, oxygen demanding organic chemicals in point source discharges, or the breakdown of naturally-occurring organic material such as leaves. The State of Maryland has established a minimum surface water criterion of 5 milligrams per liter (mg/L, also known as parts per million) for DO. When DO is low (i.e., less than 5 mg/L), only those organisms adapted to low DO can persist. In the Coastal Plain, streams typically lack riffles, where water bubbles over rocks. Riffles help to keep DO levels high by aerating the water. During MBSS summer sampling, dissolved oxygen is measured only once during the day. In heavily impacted streams, DO may drop severely during the early morning hours because oxygen production from plants ceases at night while oxygen consumption by both plants and animals continues.

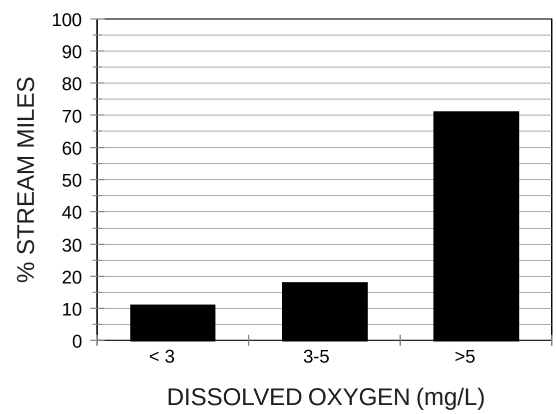


Figure 4. Dissolved oxygen concentration in non-tidal streams of the Pocomoke basin, 1997.

pH and Acid Neutralizing Capacity

Significant adverse impacts on aquatic life are known to occur when pH values fall to 5.0, and below 4.5 faunal exclusion occurs (Allan 1995, Jefferies and Mills 1990). Exposure to low pH conditions can be chronic or acute, but both may result in increased mortality

Acidity is an important aspect of stream health. The balance between free hydrogen ions (which increase acidity) and negative ions (which decrease acidity) is measured as pH. The capacity of soil or water to absorb acids without changing the ion balance is known as its buffering capacity, measured as alkalinity or Acid Neutralizing Capacity (ANC). Streams with ANC less than 0 µeq/L are acidic and have no buffering capacity. Streams with baseflow ANC between 0 and 200 µeq/L are only moderately buffered and may periodically have low pH levels during rain or snowmelt events. Those streams with ANC greater than 200 µeq/L are well-buffered. Under acidic conditions, certain metals such as aluminum are dissolved into water and reach levels that can be lethal to aquatic organisms. Acidity in streams is affected by rain, snow, fog, and atmospheric dust, geology and soil characteristics, and organic matter.

Acidification of streams can be either chronic (i.e., year-round) or episodic (seasonal or storm event-related), depending on the capacity of the stream to buffer acid inputs. Chronically acidified streams generally contain only those organisms highly tolerant of acid conditions. In contrast, streams which are only episodically acidified can and often do support less tolerant “invaders” from better buffered downstream areas during summer low flow periods.

and/or decreased reproductive success of fish and benthic macroinvertebrates.

In the Pocomoke basin, pH levels have historically been low because of soil characteristics and leaching of organic acids from decomposing materials in wetlands. As a result, nearly 35% of the basin’s stream miles have pH levels below 5.0 (Figure 5). These values represent a one-time measure and provide an indication of chronic acidification. This, however, does not exclude the possibility of acute events.

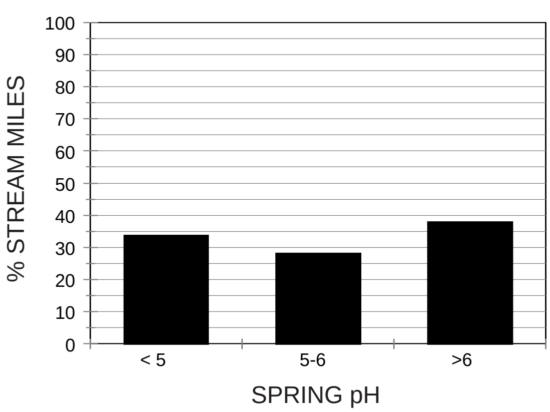


Figure 5. Spring pH values for non-tidal streams of the Pocomoke basin, 1997.

The acidic blackwater nature of the Pocomoke River is reflected in the small freshwater streams which feed it. Two of the streams sampled in 1997, Campbell Ditch and Millville Creek, had negative ANC values indicating chronic acidity. Collectively, these systems comprise approximately 14% of the basin’s first through third-order streams. Over one-half of the remaining stream miles have low (20% within 0 to 50 µeq/L) to moderate (32% within 50 to 200 µeq/L) buffering capacity and are susceptible to acidification (Figure 6). Only 34% of the stream miles are considered well-buffered and not sensitive to acid deposition.

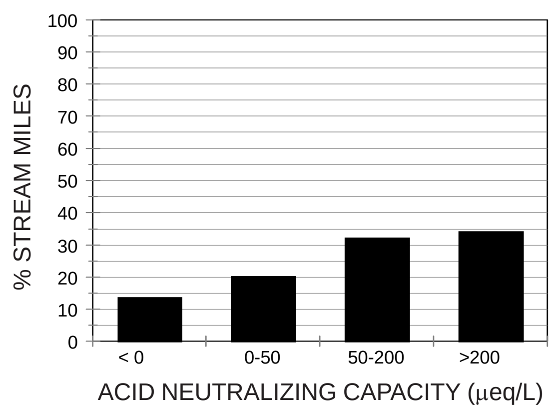


Figure 6. Acid Neutralizing Capacity (ANC) for non-tidal streams of the Pocomoke basin, 1997.

Nitrates and Dissolved Organic Carbon

Nearly 60% of the stream miles have elevated (>1 mg/L) nitrate levels, suggesting most of the streams have a problem with excess nutrients. The remaining stream miles have nitrate levels between 0.1 mg/L and 1.0 mg/L. The single grab samples collected during spring baseflow conditions represent relative nitrate contributions from groundwater inputs. Although these data do not account for seasonal or temporal variability, they do provide an effective method for identifying watersheds with elevated nutrient levels, particularly from groundwater sources. Because of the high groundwater concentrations, a reduction in point and non-point sources of nitrates to surface waters will only be recognized after groundwater sources are purged of their supplies.

Two important indicators of the sources of acidity in Maryland streams are nitrate and dissolved organic carbon (DOC).

One important source of nitrates in Maryland streams is deposition from the atmosphere. However, leaching into groundwater and direct runoff of fertilizers and animal wastes used on agricultural lands, discharges from sewage treatment plants, and leaking of septic systems are more important sources of nitrates to streams. Stream nitrate concentrations greater than 1 mg/L are elevated compared to undisturbed streams (Morgan 1995).

The primary source of DOC in streams is leachate from decaying leaves and other plant material that are natural sources of organic matter found within the stream drainage network itself, especially wetlands. DOC concentrations greater than 10 mg/L indicate that organic acids contribute significantly to overall acidity, but DOC levels between 5 and 10 mg/L also indicate that natural sources are contributing to overall acidity in a stream (Morgan 1995).

Eighty-one percent of the stream miles had DOC levels greater than 10 mg/L, suggesting that organic acids contribute significantly to overall stream acidity (Figure 7). The average DOC concentration was 13.7 mg/L; however, Kings Creek, Truitt Branch, and Millville Creek, were well above the mean with values of 24.0, 25.6, and 32.9 mg/L, respectively.

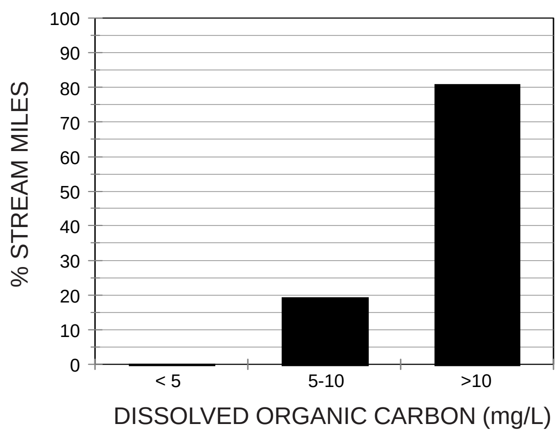


Figure 7. Dissolved Organic Carbon (DOC) for non-tidal streams of the Pocomoke basin, 1997.

PHYSICAL HABITAT

Many physical habitat characteristics of streams are important determinants of ecosystem structure and function. Although a large number of habitat variables are measured by the MBSS, they can be grouped into four general categories: instream habitat, channel character, riparian zone, and aesthetics/ remoteness. Most variables are classified as either Good, Fair, Poor, or Very Poor. A description of selected MBSS physical habitat variables is included in Appendix D.

What is habitat?
The physical/chemical theater in which the ecological play takes place; it is a template for the biota, their interactions, and their evolution (ITFM 1995).

Instream Habitat

The complexity and stability of habitat in a stream typically has the strongest relationship to abundance and diversity of the biological communities that occur there. Important instream habitat characteristics include: 1) amount and quality of stable habitat for fish shelter; 2) diversity of depths and flows; and 3) quality, composition, and heterogeneity of the stream bottom, and attachment sites for benthic macroinvertebrates.

Many instream habitat problems result from the removal or loss of woody debris from stream channels in agricultural or urban areas; reduced buffer zones between, croplands, urban lands, and streams; increased sediment loads; and increased runoff. These impacts are common when lands are developed for agricultural or urban uses. In the Pocomoke, almost two-thirds of the stream miles were rated Very Poor (29%) or Poor (33%) for instream habitat, while only twenty-one percent were considered Good (Figure 8).

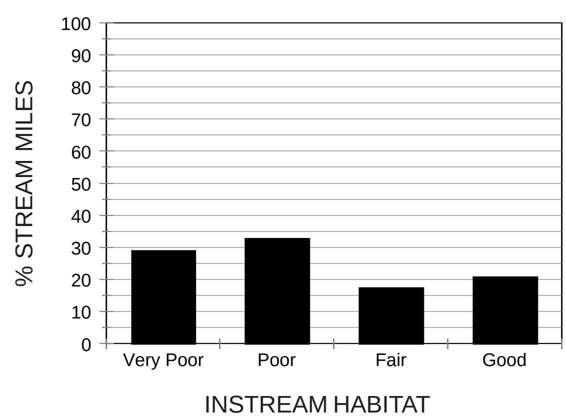


Figure 8. Instream habitat scores for non-tidal streams of the Pocomoke basin, 1997.

One factor which contributes to decreased instream habitat quality is the reduction in the abundance of wood (e.g., logs, limbs, and rootwads) along stream banks and in stream channels compared to historical levels. Wood in streams may greatly enhance habitat quality for both fish and benthic macroinvertebrates by providing a diverse array of shelter, depths, and velocities. Woody debris traps and retains leaves, a vital food supply for many benthic macroinvertebrates. By retaining organic matter in and near the stream channel, the export of nutrients to Chesapeake Bay is reduced.

There were an estimated 110 pieces of woody material per stream mile in the Pocomoke basin, slightly above the statewide average of 91 pieces per mile. However, the percent of streams that lacked any woody material was among the highest of any basin in the state at approximately 35%. These were comprised of 33% of first-order streams and 57% of second-order streams; no third-order systems lacked wood (Figure 9). As a measure of comparison, wood controls 80% or more of the stream channel in streams within old growth forests (Maser and Sedell 1994). The discrepancy between the statewide rating of pieces per mile and the number of woodless miles is likely due to the patchy distribution of woody debris which, when found, was in fairly high numbers but limited to only a few sampling sites.

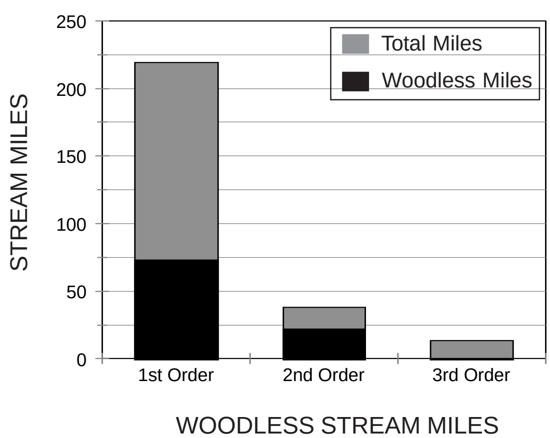


Figure 9. Woodless stream miles by stream order in the Pocomoke basin, 1997.

Added sediment loads tend to reduce the complexity and stability of the stream bottom, resulting in a loss of habitat for fish and benthic macroinvertebrates. Another common outcome is the coating or burial of stones by silt and sand in riffle areas. Since many benthic macroinvertebrates such as mayflies and stoneflies use the spaces between rocks as living quarters, high sediment loads reduce the amount of available habitat and reduce benthic macroinvertebrate diversity and abundance in streams.

A lack of stream bottom diversity was evident within the basin, with 56% of stream miles classified as Very Poor and 10% rated Poor for epifaunal substrate (Figure 10). In low gradient streams with substantial natural deposition, correlations with biological diversity or ecological health may be weak or non-existent, but this metric is rated in all streams to provide similar information from all sites statewide.

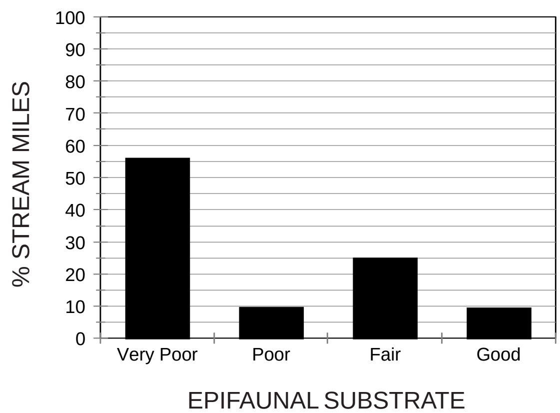


Figure 10. Epifaunal substrate scores for non-tidal streams of the Pocomoke basin, 1997.

Channel Characteristics

Large-scale disturbance in the stream channel may result from watershed development or channel modification. Evidence of stream channel disturbance includes excessive bar formation, the presence of artificial structures (e.g., concrete armoring and rip-rap), reduced stream flows because of water removal for irrigation and other uses, and severe bank erosion. Eighty-one percent of the Pocomoke's stream miles were artificially straightened or channelized in some way. During channelization, trees in the riparian zone are often cut and woody debris is removed from the stream channel to allow for efficient movement of water away from agricultural fields or housing developments. As a result, heavily channelized streams are generally shallow, with little habitat for living resources, while downstream areas suffer from increased flooding problems.

As lands within the basin were developed for agriculture and urbanized, many miles of stream channel were destabilized, as evidenced by highly eroded stream banks and sand/silt bars in slow moving areas. Twenty-three percent of the stream miles had degraded (Very Poor and Poor) channel conditions, while 26% of the stream banks were in Good condition (Figure 11). The instability of these channels limits the availability of instream habitat through sedimentation and ultimately increases nutrient and sediment transport to Chesapeake Bay.

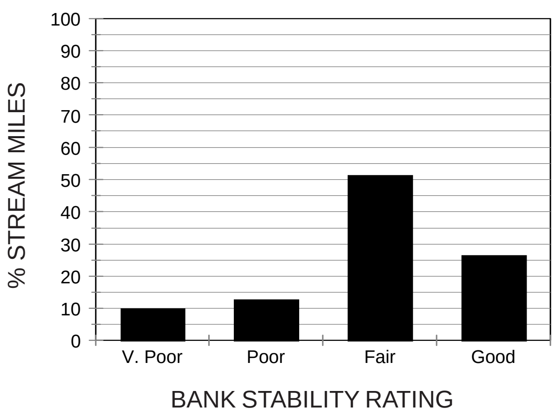


Figure 11. Bank stability rating for non-tidal streams of the Pocomoke basin, 1997.

Riparian Zone

Riparian zones are the areas alongside streams, rivers, and other water bodies. When these areas are vegetated, they play a vital role in structuring and maintaining physical habitat, energy flow, and aquatic community composition. Vegetated (trees, shrubs, and grasses) riparian zones act as buffers by decreasing runoff and preventing particulate pollutants from entering streams (Plafkin et al. 1989). Trees and shrubs also provide energy inputs to the stream in the form of leaf litter and woody debris, stabilize stream channels, supply overhead and instream cover for fishes and other aquatic life, and moderate stream water temperature.

Forest cover decreases exposure of the channel to direct sunlight and helps prevent warming of stream waters above their natural range. Other vegetation types, such as old field, mowed lawn, and tall grass, do not offer the shading extent of tree cover, but they do provide buffering of precipitation runoff and can be a food and habitat source for aquatic and terrestrial species.

In the Pocomoke, only fifty-two percent of the stream miles were considered well to moderately shaded (50% to 100% shaded) while 28% were very poorly shaded (< 25% shaded). Similarly, the condition of the riparian zone was poor. Only about 22% of the stream miles had riparian zones greater than 50 meters wide, and 22% of the miles had no vegetated buffer (Figure 12). The majority (38%) of streams had a buffer width between 19 and 49 meters wide.

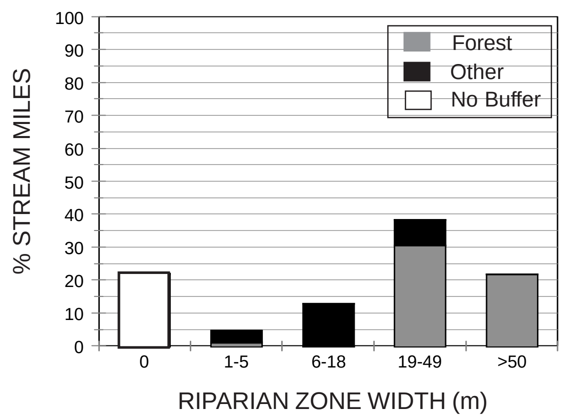


Figure 12. Riparian zone width for non-tidal streams of the Pocomoke basin,1997.

Aesthetics and Remoteness

The aesthetic and remoteness ratings provide a qualitative estimate of the level of anthropogenic influence on a stream system and, in turn, may indicate stress on the biological community. Aesthetically, Pocomoke streams rated well, with 71 percent of the stream miles in Fair or Good condition. However, remoteness ratings were less favorable with approximately 82 percent of stream miles within one-quarter of a mile from a roadway. Of this, 31 percent were immediately adjacent to a road.

HABITAT QUALITY BASED ON A PHYSICAL HABITAT INDEX (PHI)

In addition to evaluating habitat components individually, the MBSS has developed an index which combines those aspects of physical habitat that have

What is the worst stream pollution problem?

When asked this question, many people will respond with one word..."trash". Although trash in and along streams is unsightly and undesirable, it is often not the primary cause of stream degradation. However, it may be a good indicator of upstream watershed conditions. The more people living or working in a watershed, the more likely trash will end up in the stream draining the watershed. Some groups conducting stream monitoring programs are developing indices based on the number of articles of trash (such as shopping carts) at a stream site. Quantifying stream characteristics such as trash will help us gauge our success in stormwater management, public education and even recycling.

proven to be the best indicators of biological condition (Hall et al. 1999). Based on the Physical Habitat Index (PHI), more than one-half of the stream miles in the Pocomoke basin have Poor or Very Poor physical habitat, and less than 2% have Good habitat (Figure 13).

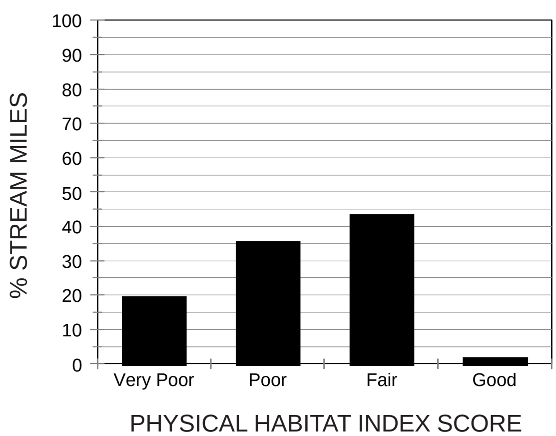
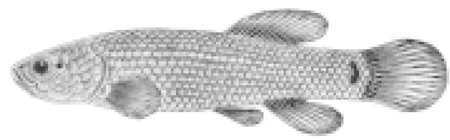


Figure 13. Physical Habitat Index (PHI) rating for non-tidal streams of the Pocomoke basin, 1997.

FISHERY RESOURCES

General Description

A total of 36 fish species representing 14 families were collected in the Pocomoke basin in first through third-order systems during 1994 and 1997. Campbell Ditch, a naturally acidic first-order stream, had the fewest species (4), while sites on the Pocomoke River and Adkins Race had the greatest number (19). Based on 1997 MBSS data, total abundance was nearly 3 million fish. Basin-wide population estimates for individual species ranged from less than 10 individuals for longnose gar to approximately 1.5 million for Eastern mudminnow (Table 1). Mudminnows, along with pirate perch, redfin pickerel, and bluespotted sunfish, make up more than 75% of the fish in the basin (Figure 14). Consistent with the presence of predominantly warm water habitat, the sunfish family (Centrarchidae) was represented by the greatest number of species (9), followed by six species of the catfish family (Ictaluridae). The remaining families were comprised of five or fewer species.



Eastern mudminnow

Species composition in the non-tidal portions of the Pocomoke is consistent with most blackwater systems. The three most abundant fishes, Eastern mudminnow, pirate perch, and redfin pickerel, are pH tolerant species and prefer lowland habitat.

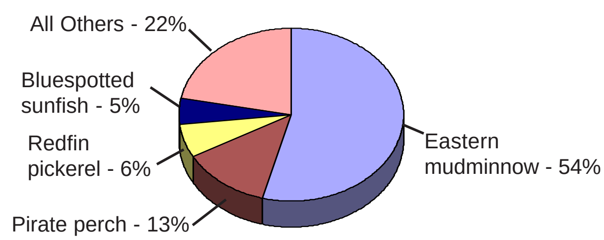


Figure 14. Composition of fish species in the Pocomoke basin, 1997.

Gamefish

Although MDNR has resource management responsibility for numerous fish species, only bass, trout, walleye, pickerel, and striped bass constitute gamefish for the MBSS. Of the 36 species present, largemouth bass and chain pickerel were the only gamefish collected. Basin-wide population estimates were approximately 1,000 for largemouth bass and about 100 for the chain pickerel (Table 1). None of the bass collected were of legal length, and only one chain pickerel was legal.

Introduced Species

Six fish species found in the Pocomoke basin (channel catfish, largemouth bass, bluegill, black crappie, green

Table 1. Estimated total abundance and percentage occurrence of fish species collected in the Pocomoke River basin in 1994 and 1997 (first, second, and third-order non-tidal streams combined).

Family / Common Name	(Scientific Name)	Percentage Occurrence[1]	Population Estimate[2,3]	Standard Error
Petromyzontidae				
Least Brook Lamprey	(*Lampetra aepyptera*)	15.2	1908	913
Lepisosteidae				
Longnose Gar	(*Lepisosteus osseus*)	2.5	4	25
Anguillidae				
American Eel	(*Anguilla rostrata*)	69.6	125884	30661
Esocidae				
Chain Pickerel	(*Esox niger*)	3.8	110	86
Redfin Pickerel	(*Esox americanus*)	74.7	183675	94179
Umbridae				
Eastern Mudminnow	(*Umbra pygmaea*)	86.1	1569539	532891
Cyprinidae				
Common Carp	(*Cyprinus carpio*)	1.3	n/a[3]	n/a[3]
Eastern Silvery Minnow	(*Hybognathus regius*)	2.5	n/a[3]	n/a[3]
Golden Shiner	(*Notemigonus crysoleucas*)	62.0	73230	30088
Satinfin Shiner	(*Notropis analostana*)	16.5	3799	3693
Swallowtail Shiner	(*Notropis procne*)	7.8	1480	752
Catostomidae				
Creek Chubsucker	(*Erimyzon oblongus*)	63.3	71276	44749
Ictaluridae				
Brown Bullhead	(*Ameiurus nebulosus*)	20.2	16142	12286
Channel Catfish	(*Ictalurus punctatus*)	1.3	24	24
Margined Madtom	(*Noturus insignis*)	15.2	877	225
Tadpole Madtom	(*Noturus gyrinus*)	40.5	112084	47190
White Catfish	(*Ameiurus catus*)	3.8	203	146
Yellow Bullhead	(*Ameiurus natalis*)	30.4	9050	4245
Aphredoderidae				
Pirate Perch	(*Aphredoderus sayanus*)	68.4	370465	231844
Fundulidae				
Mummichog	(*Fundulus heteroclitus*)	1.3	233	233
Poeciliidae				
Eastern Mosquitofish	(*Gambusia holbrooki*)	10.1	27603	20587
Moronidae				
White Perch	(*Morone americana*)	1.3	219	203
Centrarchidae				
Black Crappie	(*Pomoxis nigromaculatus*)	2.5	141	115
Bluegill	(*Lepomis macrochirus*)	44.3	18177	4393
Bluespotted Sunfish	(*Enneacanthus gloriosus*)	62.0	138378	35828
Banded Sunfish	(*Enneacanthus obesus*)	54.4	89352	49369
Green Sunfish	(*Lepomis cyanellus*)	1.3	n/a[3]	n/a[3]
Largemouth Bass	(*Micropterus salmoides*)	17.7	1010	364
Mud Sunfish	(*Acantharchus pomotis*)	11.4	2559	1436
Pumpkinseed	(*Lepomis gibbosus*)	65.8	23185	6344
Redbreast Sunfish	(*Lepomis auritus*)	21.5	4582	1948
Percidae				
Glassy Darter	(*Etheostoma vitreum*)	5.1	49	33
Shield Darter	(*Percina peltata*)	1.3	n/a[3]	n/a[3]
Swamp Darter	(*Etheostoma fusiforme*)	17.7	8203	4677
Tessellated Darter	(*Etheostoma olmstedi*)	34.2	41535	23208
Yellow Perch	(*Perca flavescens*)	16.5	4973	2623

1 Percent of all random and non-random sites where each species was collected.
2 Total abundance (number per basin) adjusted for capture efficiency (Heimbuch et al. 1997).
3 Non-random site information was not used in calculating population estimates.

sunfish, blackand carp) are not native to the Chesapeake Bay drainage, although they are naturalized. Such exotic species account for less than 1% of the total fish in the basin.

Rare and Uncommon Species

None of the fish species identified in the 1994 and 1997 survey are on the State or Federal endangered species lists (MDNR 1997b). Two species, mud sunfish and glassy darter, are listed as State rare and State endangered, respectively, by MDNR's Natural Heritage Program. In 1997, mud sunfish were observed at only 4 sites with 7 individual fish (Table 1). Similarly, two glassy darters were collected in 1997, one at Adkins Race and one in the Pocomoke River.

Migratory Species

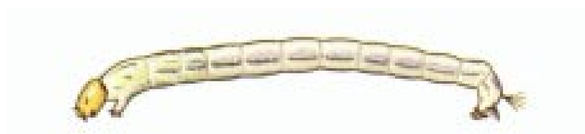
There are three types of migratory fish in Maryland, anadromous, semi-anadromous, and catadromous. Anadromous species live as adults in estuarine or marine waters, moving into freshwater to spawn. Semi-anadromous species live as adults in estuarine or riverine waters, also moving into freshwater to spawn. However, semi-anadromous species migrate lesser distances. Conversely, catadromous American eels live as adults in freshwater, migrating to marine waters to spawn.

Only three migratory species, the catadromous American eel and semi-anadromous yellow and white perch, were collected in the non-tidal portion of the basin. American eel had a basin-wide population estimated at about 126,000 individuals. Yellow and white perch were estimated at approximately 5,000 and 200 individuals, respectively. The low number of species and low abundances can be explained by sampling methods and blockages to migration. Because MBSS fish sampling was conducted from June-September, well after the spawning period for anadromous and semi-anadromous fish, few species with these life histories would be expected in the sampled streams. Additionally, there are 2 known dams, one gaging station weir, one pipeline crossing and four unknown or unclassified blockages to fish passage in the Pocomoke basin (MDNR 1999).

BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates, or more simply "benthos", are animals without backbones that are larger than 0.5 millimeter (the size of a pencil dot). These animals live on and under rocks, logs, sediment, debris, and aquatic plants during some stage of their lives. The benthos include crustaceans, such as crayfish; mollusks, such as clams and snails; aquatic worms; and the immature forms of aquatic insects, such as stonefly and mayfly nymphs.

Of the approximately 350 genera of stream-dwelling benthic macroinvertebrates in Maryland, 110 were found in the Pocomoke basin. The number of taxa per site ranged from 3 to 26. Non-biting midges were the most frequently encountered taxon, with *Conchapelopia* and *Polypedilum* present at 76% and 71 % of the sites, respectively. Other common taxa and their respective percent occurrence (among all sites in the basin) were: *Caecidotea* (an isopod; 65%), *Stegopterna* (a blackfly; 50%), *Cragonyx* (an amphipod; 44%) and *Polycentropus* (a caddisfly; 44%). Rare taxa (found at 3 % or less of all sites), include *Vivaparus* (a snail), *Corbicula* (a clam), *Gyrinidae* (a whirlygig beetle) and *Triopisternus* (a biting midge). A list of all benthic taxa collected in the basin and their associated feeding groups and tolerance classifications is presented in Appendix F.



STREAM QUALITY BASED ON AN INDEX OF BIOTIC INTEGRITY (IBI)

MDNR recently developed an Index of Biotic Integrity (IBI) for non-tidal stream fish (Roth et al.1997) and benthic macroinvertebrate (Stribling et al. 1998) communities that are effective tools for evaluating ecological conditions in streams. Using these IBIs, various characteristics of the fish and benthic community are compared to results from high quality reference streams and scored. The summary score is then used to assess ecological conditions of streams in the basin as Good, Fair, Poor, or Very Poor.

The results of the fish and benthic macroinvertebrate IBIs indicate some biological impairment throughout the Pocomoke basin (Figures 15 - 17). Nearly fifty percent of the streams miles were rated Fair or better using the fish IBI. However, only 13 percent were rated Fair or better when assessed with the benthic macroinvertebrate IBI. In addition, over twenty-five

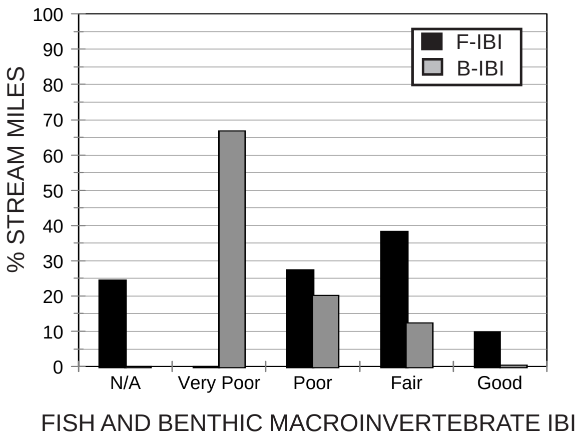


Figure 15. Fish (F-IBI) and benthic macroinvertebrate (B-IBI) Index of Biotic Integrity scores for non-tidal streams of the Pocomoke basin, 1997.
*N/A (Not Assessed) - sub-watershed <300 acres

percent of the streams were rated Poor or Very Poor by the fish IBI, and the majority of sites within the Fair rating of both IBIs fell within the lower range of that category. This suggests that although current biological impairment is not prevalent, the potential exists for widespread biotic degradation.

Approximately twenty-five percent of the stream miles were not eligible for the fish IBI because of the watershed size criterion of the index. Because of the inherent physical limitations of streams in small watersheds (i.e., small channel dimensions and lack of stable water flow) and the effect on fish community dynamics, sites with less than a 300 acre watershed were excluded from the analysis. However, benthic macroinvertebrates are less affected by these conditions and thus were not limited by the size of the watershed. The discrepancy between the indices may be attributed to several factors, including each IBI's classification rating, differences in response to environmental stress between fish and benthic macroinvertebrates, and the number of sites assessed by each IBI. A detailed discussion of these factors is presented in Chapter 5.

REPTILES AND AMPHIBIANS

Reptiles and amphibians were found at 39 of the 42 quantitative sites sampled in 1994 and 1997. Frogs and toads were the most frequently encountered group, with green frogs and bullfrogs occurring at 81% and 48% of the sites, respectively (Table 2). With the exception of the Southern leopard frog, the remaining species all occurred at less than twenty percent of the sites. Only one occurrence was noted for the Northern black racer, Eastern box turtle, and wood frog.

Table 2. List of herpetofauna observed in the Pocomoke basin, 1994 and 1997.

Frogs and Toads		**Freq. (%)**
Bullfrog	*(Rana catesbeiana)*	47.6
Green Frog	*(Rana clamitans melanota)*	80.9
Fowlers Toad	*(Bufo woodhousii fowleri)*	11.9
S. Leopard Frog	*(Rana utricularia)*	28.6
Wood Frog	*(Rana sylvatica)*	2.4
Turtles		
Common Musk Turtle	*(Sternotherus odoratus)*	9.5
Common Snapping Turtle	*(Chelydra serpentina)*	14.3
E. Box Turtle	*(Terrapene carolina carolina)*	2.4
E. Painted Turtle	*(Chrysemys picta picta)*	19.0
Snakes and Lizards		
Black Rat Snake	*(Elaphe obsoleta obsoleta)*	4.8
N. Black Racer	*(Coluber constrictor constrictor)*	2.4
N. Water Snake	*(Nerodia sipedon sipedon)*	11.9

FRESHWATER MUSSELS

Freshwater mussels were rare in the Pocomoke basin. Three species, the Asiatic clam (*Corbicula fluminea*), Eastern elliptio (*Elliptio complanata*), and Northern lance (*Elliptio fisheriana*) were collected at approximately 39, 36, and 4 percent of the 1997 sampling sites, respectively. Seventy-seven percent of the mussels collected were found at third-order sites; no first-order sites had freshwater mussels.

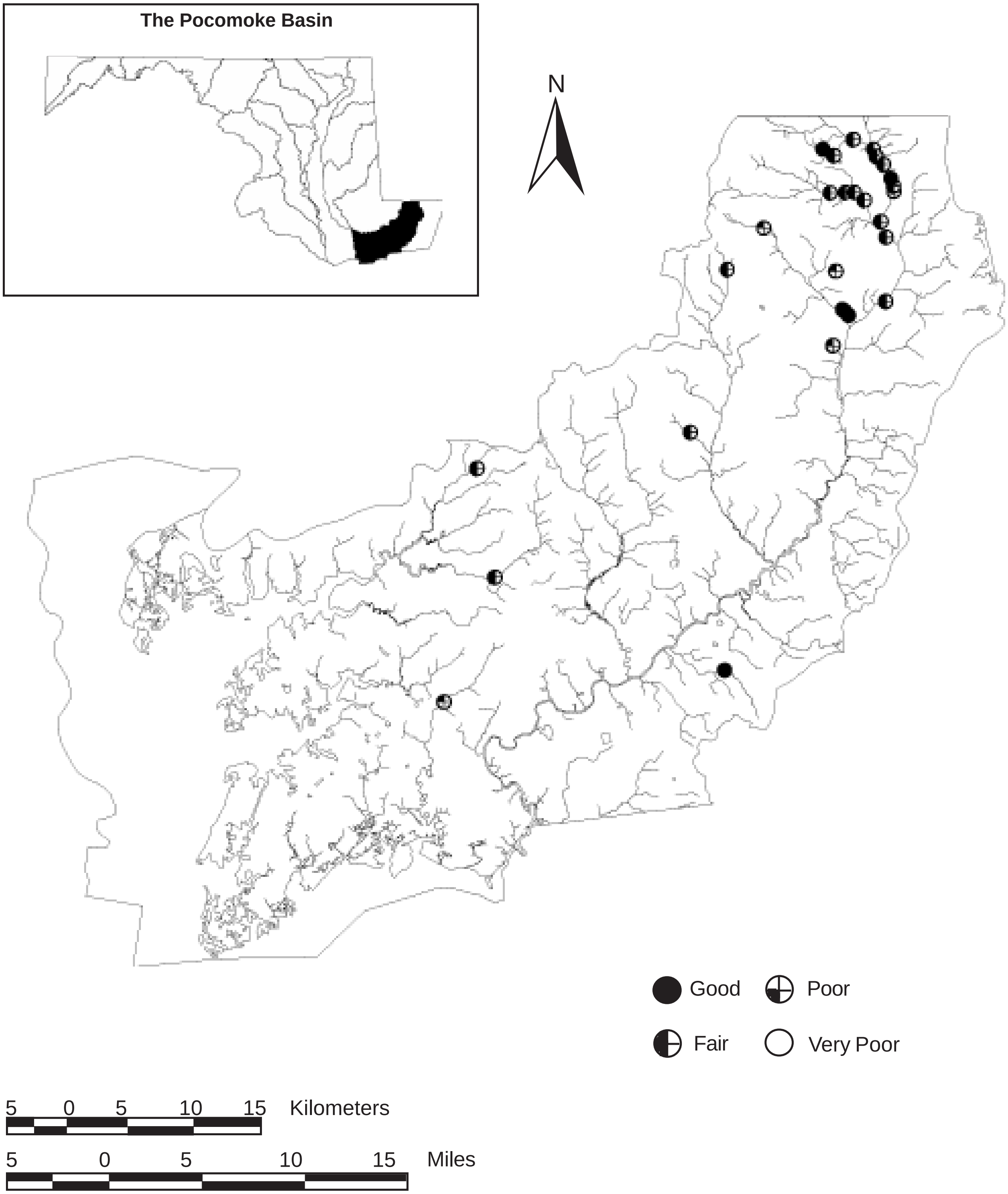


Figure 16. Stream ecological conditions in the Pocomoke basin based on the Fish Index of Biotic Integrity (F-IBI), 1997.

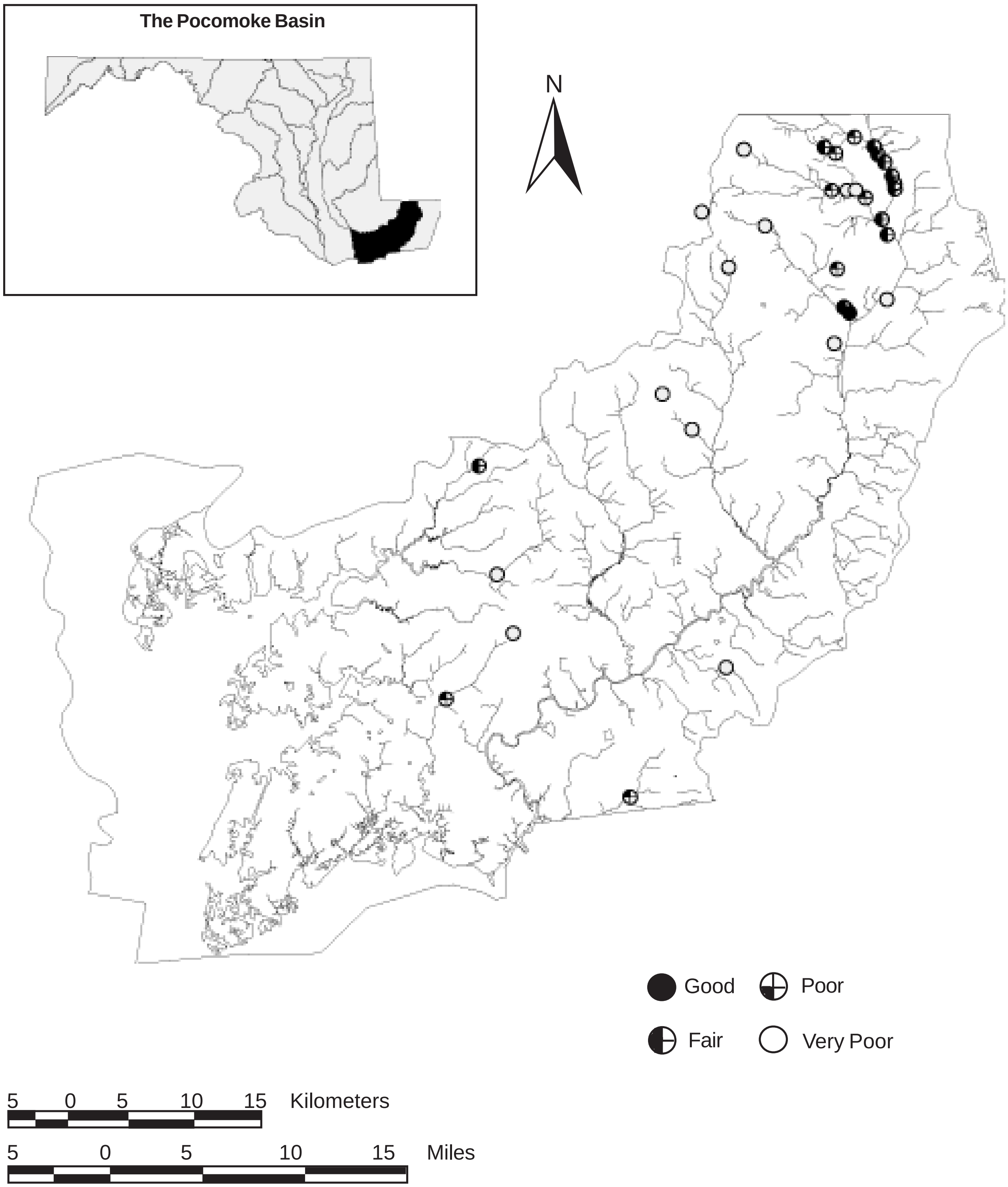


Figure 17. Stream ecological conditions in the Pocomoke basin based on the benthic macroinvertebrate Index of Biotic Integrity (B-IBI), 1997.

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Information from the Maryland Biological Stream Survey has provided us with a snapshot of living resources, stream conditions, and major stressors to the aquatic habitat in the Pocomoke basin. Like most Maryland watersheds, the Pocomoke consists of a network of streams that range in quality from extremely degraded to relatively healthy. MBSS' one-time measurements of dissolved oxygen, pH, and acid neutralizing capacity indicate that many streams violate state water quality criteria.

About thirty percent of streams in the basin violated state water quality criteria for dissolved oxygen or pH. Low pH values are likely the result of natural conditions, as indicated by the high DOC values, while low dissolved oxygen concentrations can be the result of human practices and land use changes that increase nutrient loads. Elevated nitrate-nitrogen levels were common (~60% of stream miles) and related to the proportion of land in agricultural use (Figure 18 and 19; next page). Urban runoff and point source inputs are major contributors of excess nitrate, however, agricultural practices are probably the most important source of nitrate-nitrogen in streams in the basin. Because this condition represents both current and historical nutrient additions, it may be years to decades before the benefits of nutrient reduction efforts begin to be realized.

In addition to failing to meet water quality standards (a result common to other surveys which only measure water chemistry), there is evidence of biological impairment in Pocomoke basin streams. The MDNR's fish Index of Biotic Integrity classified nearly 20% of the stream miles as Poor. The results of the benthic IBI were more dramatic, classifying almost 62% of the stream miles as Poor or Very Poor. Also, the majority of sites classified as Fair scored within the lower range of that category and are therefore susceptible to being degraded to Poor condition. Unlike other basins, IBI scores of the Pocomoke do not exhibit any trends with associated land use practices. Typically, IBIs are inversely related to urban land use, but given that urbanization is not widespread in the basin this relationship was not apparent.

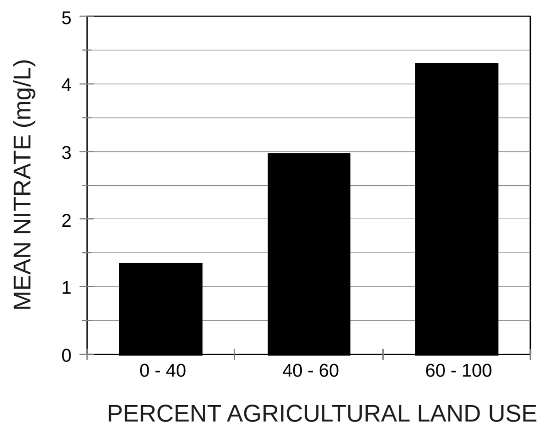

Figure 18. Agricultural land use and nitrate concentration at MBSS sites in the Pocomoke basin, 1997.

The discrepancy of the ratings between the IBIs may be attributed to several factors. First, the classification efficiencies of the fish and benthic IBIs are 82% and 88%, respectively. The error associated with each index likely accounts for some of the disagreement. Second, it has been established that because of differences in trophic level, life history patterns, and responses to environmental stressors, fish and benthic macroinvertebrates reflect different types of environmental perturbations. Fish generally respond to larger, landscape scale influences while the benthic macroinvertebrate community reflects water chemistry and instream habitat. Finally, nearly one-quarter of the stream miles could not be assessed by the fish IBI because of the minimum 300 acre watershed size criterion. The difference in the number of sites assessed by each IBI could affect the overall evaluation of the basin, particularly because these smaller first and second-order streams make up 94 percent of the streams in the basin.

Another potential influence on the outcome of the fish and benthic IBIs is that each index has been calibrated for Coastal Plain and non-Coastal Plain streams, but many sub-watersheds in the Pocomoke basin contain "blackwater" streams with naturally occurring conditions that are different from the "typical" Coastal Plain system. Blackwater systems are naturally acidic, with low flow streams, swamps, and

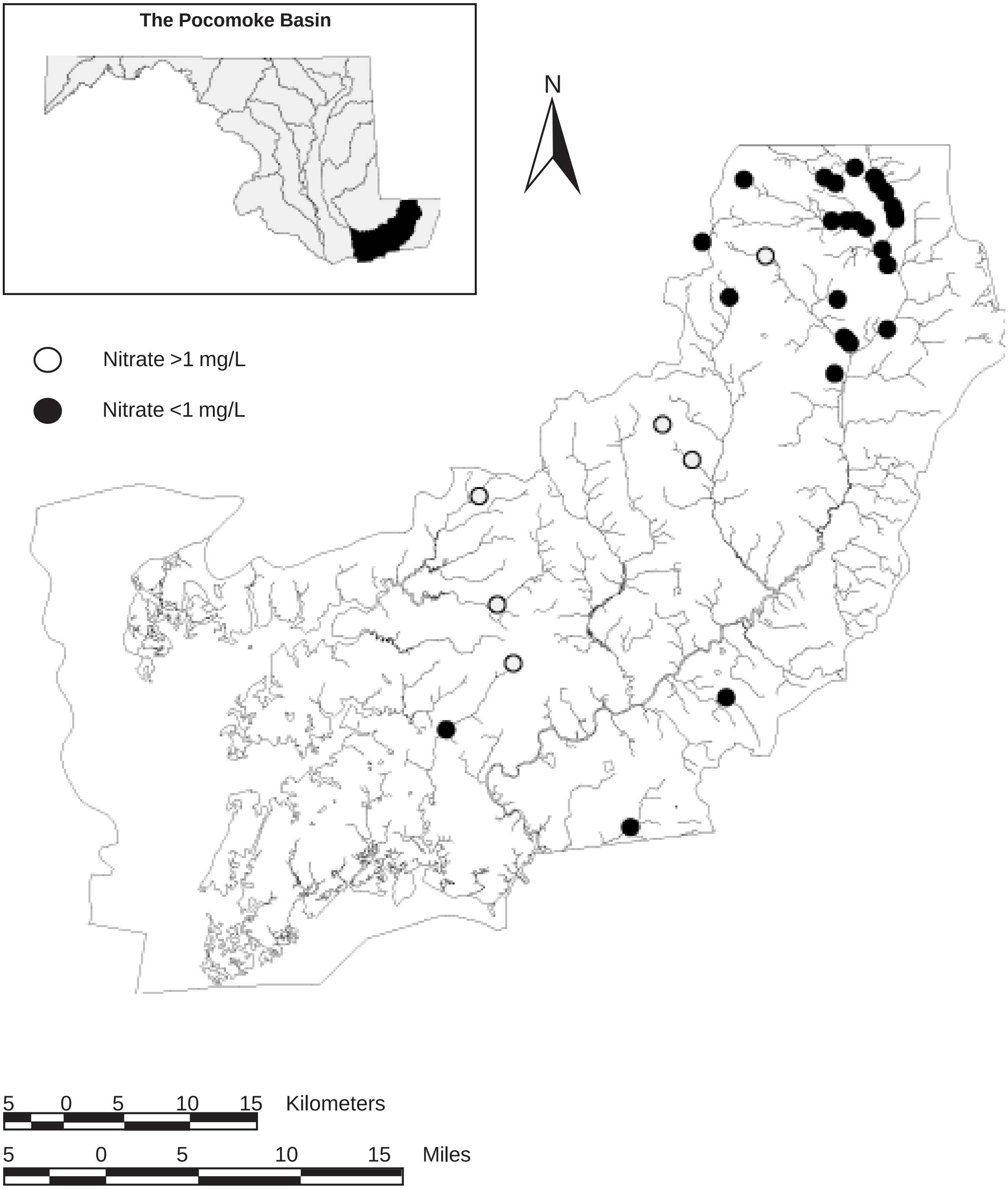

Figure 19. Nitrate concentrations (mg/L) in the Pocomoke basin, 1997.

marsh lands. Because of the somewhat inhospitable conditions, the biological communities of these systems are unique and, in terms of composition and abundance, may differ from other Coastal Plain systems.

Only 2% of streams in the basin appear to be in Good condition based on the Physical Habitat Index, with 54% of the stream miles in Poor or Very Poor condition. This degradation is largely the result of a lack of rootwads and woody debris in the stream channel from historical and ongoing logging practices; excess silt and unstable stream banks; modification of stream channels; and loss of functional riparian buffers. Large woody debris and rootwads function to reduce the erosive power of water. Without these natural structures bank instability intensifies, although in many cases marshes fill the functional niche of wood and rootwads. About 23% of all stream miles in the Pocomoke River basin have unstable or moderately unstable stream banks. Unstable bank conditions increase the amount of sediment that enters the stream and, in turn, increases siltation, reducing habitat available for benthos and food supplies for fish. The problem of bank erosion is further compounded in streams that experience increased runoff due to land use changes that increase impervious surface or decrease the amount of stabilizing vegetation. Lastly, 22% of the streams in the basin have no functional (vegetated) riparian buffer, reducing the ecological integrity of the stream and threatening downstream areas. This lack of protective vegetation along streams is an obvious starting point in the restoration process because riparian buffers improve both water quality and physical habitat in several ways. In general, results of the MBSS suggest that physical habitat degradation is an important, widespread problem in the basin.

Fish community diversity in non-tidal streams of the basin is among the lowest of the state's eighteen river basins, but fairly typical of Coastal Plain streams. Six of the 36 species of fish collected are non-native and most, if not all, of these species were introduced by fishery managers or anglers. From a recreational standpoint, some of these introductions have been beneficial, but ecological impacts, such as the reduction in distribution and abundance of native species, have occurred and will continue. Unfortunately, there is little historical information about fish community composition in the basin. Therefore, it is difficult to determine if the introduction of non-native fishes has influenced the distribution and abundance of native species. The MBSS results establish a useful benchmark of current fish species composition, distribution, and abundance that can be used to track future changes. Because of the recognized potential for detrimental effects, the Chesapeake Bay states have started a review process for proposed introductions of non-native species that should reduce the number of unwise introductions.

Only two species of gamefish were collected: largemouth bass and chain pickerel. Largemouth bass, popular among anglers, were the most abundant gamefish in the basin but were found at the lowest numbers in the state. The native chain pickerel was found at the forth lowest abundance in the state. None of the specimens collected were of legal size.

American eel, yellow perch and white perch were the only migratory species documented in the Pocomoke basin. Of these, American eel were the most abundant species. The Pocomoke drainage has 8 known barriers to anadromous fish movement (MDNR 1999). The prevalent type of blockages are dams, and the majority of blockages are found on small streams. With future expansion of housing and other development, the number of pipe crossings and culverts will likely increase as more roads and sewage systems are constructed, thus reducing the amount of habitat accessible to migratory fish.

The amount of rain and snow falling onto a watershed is an important factor in shaping the biological community of a stream. Dry, low flow periods are considered stressful to aquatic life due to higher water temperatures, lower dissolved oxygen levels, and a reduction in the amount of available habitat. Conversely, extremely heavy rainfall and high flows may result in large-scale changes in physical habitat, temporarily lethal water quality conditions, mortality of bottom-dwelling species through crushing and burial by moving rocks and sediments, and transport of aquatic animals to less favorable habitats.

In 1997, the total annual rainfall in the Pocomoke basin was about 2.5 percent above average (Figure 20;

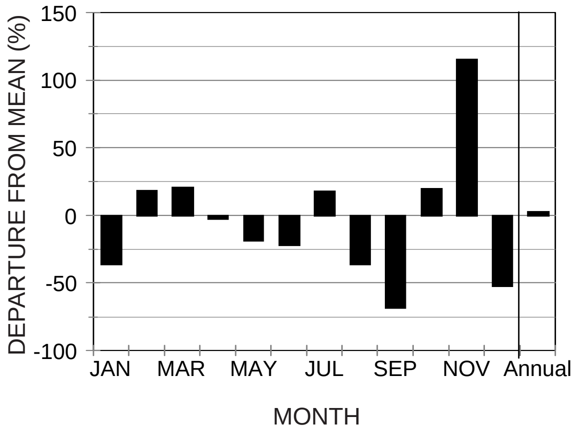

Figure 20. Monthly rainfall in the Pocomoke basin (1997). Bars indicate the departure, expressed as a percentage, from the average monthly rainfall from 1960 through 1997.

NOAA 1997). However, a dry growing season (April through August) may have caused significant stress to stream biota in the basin. The roughly 7.25 inches of rain that fell in November not only made up for the yearly water deficit, but may have provided an additional stress to stream biota, resulting in reduced species richness and abundance of fish and benthic macroinvertebrates. Without long-term climatological data, flow, and stream ecological conditions, it is difficult to determine relationships among these environmental factors and stream quality. When the MBSS is repeated in future years, more light will be shed on this important subject.

Given the level and types of stream impacts noted in 1997 and the projected changes in land use, human population size, and water demands in the Pocomoke basin, the biological communities and other ecological attributes of streams in the basin will likely become more degraded in years to come. Comprehensive implementation of best management practices (BMPs), such as riparian zone protection and reforestation, may partially offset these impacts. However, it is important to note that BMPs may reduce, but not eliminate, the ecological impacts of human disturbance. Just as it took time for detrimental practices to be felt in the environment, it will take time for the effects of remediation efforts to show a positive change. The "snapshot" quality of MBSS sampling will make these changes, both good and bad, easier to detect.

This report illustrates that valuable stream resources still exist, however, in many ways the basin still suffers from mistakes of the past. The entire area has been logged, including riparian zones, and as a result unstable stream channels are common, physical habitat has been greatly reduced, and even forested streams carry elevated sediment loads. In addition, dams and other migration barriers exclude many fish species from usable stream habitat. In many areas, large volumes of water flush directly into streams during storms and stream flows are reduced to a trickle during dry periods. These extreme fluctuations in flow create conditions that only the hardiest of aquatic animals can tolerate. These problems can be lessened or eliminated, but great cost is typically involved. Over time, we must work to restore conditions in the basin for future generations. We also need to make a concerted effort to protect and enhance the remaining high quality resources in the basin, and elsewhere. Only in this way can we learn to exist in a sustainable manner.

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SYNOPSIS OF MBSS DESIGN AND SAMPLING METHODS

The MBSS is intended to provide unbiased estimates of the condition of streams and rivers of Maryland on a local (e.g., drainage basin or county) as well as a statewide scale. To date, the MBSS has focused on wadeable, headwater streams. The survey is based on a probabilistic stream sampling approach where random selections are made from all sections of streams in the state which can physically be sampled. The approach supports statistically-valid population estimation of variables of interest (e.g., largemouth bass densities, miles of streams with degraded physical habitat, etc.). When repeated, the MBSS will also provide a basis for assessing future changes in ecological condition of flowing waters of the state. At present, plans are to continue the MBSS and develop a quantitative sampling approach for larger streams and rivers.

The study area for the MBSS includes each of the 18 major drainage basins of the state, and a total of three years was required to sample all 18 basins. For logistical reasons, the state was divided into three geographic regions (east, west, and central) with five to seven basins in each region. Each basin was sampled at least once during the three year cycle, and one basin in each region was sampled twice so that data collected in different years could be combined into a single statewide estimate for each of the variables of interest.

The sampling frame for the MBSS was constructed by overlaying basin boundaries on a map of all blueline stream reaches in the state as digitized on a U.S. Geological Survey 1:250,000 scale map. Sampling within basins was restricted to non-tidal, first, second and third-order (Strahler 1964) stream reaches, excluding unwadeable or otherwise unsampleable areas. An additional restriction was that only public land or privately-owned sites where landowner permissions was obtained were sampled.

During 1995 the MBSS sample sites were selected from a comprehensive list of headwater stream reaches in 6 of the 18 drainage basins. In 1996, sample sites were selected from 7 basins, and in 1997 the remaining basins were sampled. To provide adequate information about each size of stream, an approximately equal number of first, second and third-order streams were sampled during spring and summer, with the number of sites of each order in a basin being proportional to the number of stream miles (of an order) in the entire state.

Benthic macroinvertebrates and water quality samples were collected during the spring index period from March through early May, while fish, herpetofauna, *in situ* stream chemistry and physical habitat sampling were conducted during the low flow period in the summer, from June through September.

In the spring, water samples were collected and analyzed for pH, acid-neutralizing capacity (ANC), sulfate (SO_4), nitrate (NO_3), conductivity, and dissolved organic carbon (DOC) in the laboratory. These variables primarily characterize the sensitivity of the streams to acid deposition, and to other anthropogenic stressors to a lesser extent. Benthic macroinvertebrates collected in the spring were identified to family and genus level in the laboratory.

Habitat assessments were conducted in the summer using metrics largely patterned after EPA's Rapid Bioassessment Protocols and Ohio EPA's Qualitative Habitat Evaluation Index (QHEI) described by Rankin (1989), Plafkin *et al.* (1989), and Platts *et al.* (1983) in the designated 75 m length of the stream segments; riparian habitat measurements were based on the surrounding area within 20 m of the segment. Other qualitative measurements included (1) aesthetic value, based on evidence of human refuse; (2) remoteness, based on the absence of detectable human activity and difficulty in accessing the segment; (3) land use, based on the surrounding area immediately visible from the segment; (4) general stream character, based on the shape, substrate, and vegetation of the segment; and (5) bank erosion, based on the kind and extent of erosion present. Quantitative measurements at each segment included flow, depth, wetted width, and stream gradient.

Fish and herpetofauna were sampled during the summer index period using quantitative, double-pass electrofishing of the 75 m stream segments. Blocking nets were placed at each end of the segment, and one or more direct-current, backpack electrofishing units were used to sample the entire segment. All fish captured during each electrofishing pass were identified, counted, weighed in aggregate, and up to 100 individuals of each species were examined for external anomalies such as lesions and tumors. All gamefish captured were also measured for length. Any amphibians, reptiles, freshwater molluscs, submerged aquatic vegetation either in or near the stream segment were collected and identified.

For all phases of the MBSS, there was a ongoing, documented program of quality assurance/quality control (QA/QC). The QA/QC program used by the MBSS allows for generation of data with known confidence.

STREAMS SAMPLED IN THE POCOMOKE BASIN IN 1997 AS PART OF THE MARYLAND BIOLOGICAL STREAM SURVEY (MBSS) (QUANTITATIVE SAMPLES ONLY)

As described in Chapter 3 and Appendix B, MBSS sampling sites were randomly selected from 1:250,000 scale maps. Many very small streams were selected-some with names and some without. Stream names were acquired for the MBSS database from several map sources.

Stream Name	Order	Stream Name	Order
Campbell Ditch	1	Burnt Mill Branch (2 sites)	2
Duncan Ditch	1	Forest Grove Branch	2
Jones Ditch	1	Green Run	2
Kings Creek	1	North Fork To Green Run	2
Lorretto Branch	1	South Fork Green Run	2
Marumsco Creek	1	Adkins Race (3 sites)	3
Millville Creek	1	Burnt Mill Branch	3
Murray Branch	1	Pocomoke River (9 sites)	3
Truitt Branch	1		

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Appendix C: Location and water quality data for MBSS sites in the Pocomoke basin, 1997. Temperature and Dissolved Oxygen (DO) were measured in the summer while all other parameters were measured during the spring. Units of measure for temperature are degrees Celcius. DO, nitrate nitrogen (NO_3), sulfate (SO_4), and dissolved organic carbon (DOC) are presented in mg/L, and acid neutralizing capacity (ANC) is measured as μeq/L.

Stream Name	Latitude	Longitude	Temp.	DO	pH	ANC	NO_3
Kings Cr.	38.1560	75.6520	12.60	8.00	4.99	22.70	0.67
Marumsco Cr.	38.0760	75.6950	13.50	5.20	5.95	158.90	1.24
Lorretto Br.	38.2270	75.6650	16.20	5.90	5.73	122.80	0.59
South Fork Green Run	38.4310	75.3750	30.90	7.80	6.49	232.90	4.52
Green Run	38.4260	75.3660	28.90	9.60	6.51	180.60	5.21
Burnt Mill Br.	38.3970	75.3420	20.20	9.00	6.28	252.60	4.53
Forest Grove Br.	38.3540	75.4560	24.40	1.00	6.48	211.90	1.41
Pocomoke R.	38.3310	75.3260	22.70	6.40	6.20	206.70	2.87
Adkins Race	38.3260	75.3620	19.00	5.80	6.32	173.10	2.28
Adkins Race	38.3220	75.3570	15.90	6.90	6.34	173.20	2.22
Adkins Race	38.3250	75.3600	18.80	6.80	6.55	261.50	1.48
Truitt Br.	38.3510	75.3670	20.40	6.90	5.98	202.10	4.82
Burnt Mill Br.	38.4020	75.3700	20.80	7.80	6.30	223.30	4.05
Burnt Mill Br.	38.4020	75.3580	21.50	7.70	6.52	274.20	2.56
Murray Br.	38.4020	75.3500	26.50	8.70	6.31	262.70	4.29
Campbell Ditch	38.3800	75.4260	19.70	3.40	4.57	-26.90	0.52
Duncan Ditch	38.3030	75.3700	19.30	7.10	6.09	124.00	5.41
Pocomoke R.	38.4060	75.3180	25.30	5.90	6.00	128.60	3.36
Pocomoke R.	38.4020	75.3180	24.80	6.00	5.93	134.50	3.32
Pocomoke R.	38.4200	75.3250	25.10	5.70	6.12	169.20	2.65
Pocomoke R.	38.3830	75.3290	24.90	6.30	6.15	164.10	2.77
Pocomoke R.	38.4110	75.3200	26.50	5.50	6.29	186.10	2.09
Jones Ditch	38.0930	75.4640	18.80	3.50	6.41	221.40	1.46
Pocomoke R.	38.3730	75.3240	23.90	6.90	6.23	205.00	2.92
Pocomoke R.	38.4300	75.3340	22.00	7.10	6.00	135.00	3.77
Pocomoke R.	38.4250	75.3320	21.40	6.00	6.24	178.60	2.09
Millville Cr.	38.2480	75.4890	18.10	1.50	4.40	-64.60	0.35
N. Fork To Green Run	38.4370	75.3500	23.90	7.90	6.38	231.70	4.73

Appendix C: Location and water quality data for MBSS sites in the Pocomoke basin, 1997. Temperature and Dissolved Oxygen (DO) were measured in the summer while all other parameters were measured during the spring. Units of measure for temperature are degrees Celcius. DO, nitrate nitrogen (NO_3), sulfate (SO_4), and dissolved organic carbon (DOC) are presented in mg/L, and acid neutralizing capacity (ANC) is measured as µeq/L.

Stream Name	Latitude	Longitude	SO_4	DOC
Kings Cr.	38.1560	75.6520	11.99	24.00
Marumsco Cr.	38.0760	75.6950	21.12	15.80
Lorretto Br.	38.2270	75.6650	17.89	7.80
South Fork Green Run	38.4310	75.3750	14.57	11.70
Green Run	38.4260	75.3660	14.92	10.40
Burnt Mill Br.	38.3970	75.3420	15.26	11.10
Forest Grove Br.	38.3540	75.4560	12.54	14.60
Pocomoke R.	38.3310	75.3260	14.32	11.70
Adkins Race	38.3260	75.3620	10.79	13.40
Adkins Race	38.3220	75.3570	10.89	14.30
Adkins Race	38.3250	75.3600	9.56	15.80
Truitt Br.	38.3510	75.3670	17.29	25.60
Burnt Mill Br.	38.4020	75.3700	14.74	9.10
Burnt Mill Br.	38.4020	75.3580	12.95	9.70
Murray Br.	38.4020	75.3500	14.79	10.70
Campbell Ditch	38.3800	75.4260	7.25	10.90
Duncan Ditch	38.3030	75.3700	16.10	10.60
Pocomoke R.	38.4060	75.3180	13.04	12.90
Pocomoke R.	38.4020	75.3180	12.92	12.30
Pocomoke R.	38.4200	75.3250	11.84	11.60
Pocomoke R.	38.3830	75.3290	12.45	11.80
Pocomoke R.	38.4110	75.3200	11.56	13.30
Jones Ditch	38.0930	75.4640	19.61	15.10
Pocomoke R.	38.3730	75.3240	13.00	10.70
Pocomoke R.	38.4300	75.3340	13.26	11.00
Pocomoke R.	38.4250	75.3320	11.32	13.50
Millville Cr.	38.2480	75.4890	3.99	32.90
N. Fork To Green Run	38.4370	75.3500	15.02	8.10

PHYSICAL HABITAT CONDITIONS MEASURED BY THE MBSS

I. SUBSTRATE AND INSTREAM COVER

Instream Habitat is rated according to the perceived value of habitat to the fish community. Higher scores are assigned to sites with a variety of habitat types and particle sizes. In addition, higher scores are assigned to sites with a high degree of uneven substrate. In streams where substrate types are favorable but flows are so low that fish are essentially precluded from using the habitat, low scores are assigned. If none of the habitat within a segment is useable by fish, a score of zero is assigned.

Epifaunal Substrate is rated based on the amount and variety of hard, stable substrates usable by benthic macroinvertebrates. Because they inhibit colonization, flocculent materials or fine sediments surrounding otherwise good substrates are assigned low scores. Scores are also reduced when substrates are less stable.

Velocity/Depth Diversity is rated based on the variety of velocity/depth regimes present at a site (slow-shallow, slow-deep, fast-shallow, and fast-deep). As with embeddedness, this metric may result in lower scores in low-gradient streams but will provide statewide information on the physical habitat found in Maryland streams.

Pool/Glide/Eddy Quality is rated based on the variety and spatial complexity of slow or still water habitat within the sample segment. In high-gradient streams, functionally important slow water habitat may exist in the form of larger eddies. Within a category, higher scores are assigned to segments which have undercut banks, woody debris or other types of cover for fish.

Riffle/Run Quality is based on the depth, complexity, and functional importance of riffle/run habitat in the segment, with highest scores assigned to segments dominated by deeper riffle/run areas, stable substrates, and a variety of current velocities.

Embeddedness is a percentage of surface area of larger particles that is surrounded by fine sediments on the stream bottom. In low gradient streams, embeddedness may be high even in unimpaired streams.

II. CHANNEL CHARACTER

Channel Alteration is a measure of large-scale changes in the shape of the stream channel. Channel alteration includes: concrete channels, artificial embankments, obvious straightening of the natural channel, rip-rap, or other structures, as well as recent bar development. Ratings for this metric are based on the presence of artificial structures as well as the existence, extent, and coarseness of point bars, side bars, and mid-channel bars which indicate the degree of flow fluctuations and substrate stability. Evidence of channelization may sometimes be seen in the form of berms which parallel the stream channel.

Bank Stability is rated based on the presence/absence of riparian vegetation and other stabilizing bank materials such as boulders and rootwads, and frequency/size of erosional areas. Sites with steep slopes are not penalized if banks are composed solely of stable materials.

Channel Flow Status is the percentage of the stream channel that has water, with subtractions made for exposed substrates and dewatered areas.

III. RIPARIAN CORRIDOR

Shading is rated based on estimates of the degree and duration of shading at a site during summer, including any effects of shading caused by land forms.

Riparian Buffer is rated according to the size and type of the vegetated riparian buffer zone at the site. Cultivated fields for agriculture which have bare soil to any extent are not considered as riparian buffers. At sites where the buffer width is variable or direct delivery of storm runoff or sediment to the stream is evident or highly likely, the narrowest representative buffer width in the segment (e.g., 0 if parking lot runoff enters directly to the stream) is measured and recorded even though some of the stream segment may have a well developed riparian buffer.

IV. AESTHETICS/REMOTENESS

Aesthetics are rated according to the visual appeal of the site and presence/absence of human refuse, with highest scores assigned to stream segments with no human refuse and visually outstanding character.

Remoteness is rated based on the absence of detectable human activity and difficulty in accessing the segment.

MBSS Habitat Assessment Guidance Sheet

Habitat Parameter	Optimal 16-20	Sub-Optimal 11-15	Marginal 6-10	Poor 0-5
1. Instream Habitat(a)	Greater than 50% mix of a variety of cobble, boulder, submerged logs, undercut banks, snags, rootwads, aquatic plants, or other stable habitat	30-50% mix of stable habitat. Adequate habitat	10-30% mix of stable habitat. Habitat availability less than desirable	Less than 10% stable habitat. Lack of habitat is obvious
2. Epifaunal Substrate(b)	Preferred substrate abundant, stable, and at full colonization potential (riffles well developed and dominated by cobble; and/or woody debris prevalent, not new, and not transient)	Abund. of cobble with gravel &/or boulders common; or woody debris, aquatic veg., under-cut banks, or other pro-ductive surfaces common but not prevalent /suited for full colonization	Large boulders and/or bedrock prevalent; cobble, woody debris, or other preferred surfaces uncommon	Stable substrate lacking; or particles are over 75% surrounded by fine sediment or flocculent material
3. Velocity/Depth Diversity(c)	Slow (<0.3 m/s), deep (>0.5 m); slow, shallow (<0.5 m); fast (>0.3 m/s), deep; fast, shallow habitats all present	Only 3 of the 4 habitat categories present	Only 2 of the 4 habitat categories present	Dominated by 1 velocity/depth category (usually pools)
4. Pool/Glide/Eddy Quality(d)	>50% pool/glide/eddy habitat; both deep (>.5 m)/shallows (<.2 m) present; complex cover/&/or depth >1.5 m	10-50% pool/glide/eddy habitat, with deep (>0.5 m) areas present; or >50% slow water with little cover	<10% pool/glide/eddy habitat, with shallows (<0.2 m) prevalent; slow water areas with little cover	Pool/glide/eddy habitat minimal, with max depth <0.2 m, or absent completely
5. Riffle Quality(e)	Riffle/run depth generally >10 cm, with maximum depth greater than 50 cm (maximum score); substrate stable (e.g. cobble, boulder) & variety of current velocities	Riffle/run depth generally 5-10 cm, variety of current velocities	Riffle/run depth generally 1-5 cm; primarily a single current velocity	Riffle/run depth < 1 cm; or riffle/run substrates concreted
6. Channel Alteration(f)	Little or no enlargement of islands or point bars; no evidence of channel straightening or dredging; 0-10% of stream banks artificially armored or lined	Bar formation, mostly from coarse gravel; and/or 10-40% of stream banks artificially armored or obviously channelized	Recent but moderate deposition of gravel and coarse sand on bars; and/or embankments on both banks; and/or 40-80% of banks artificially armored; or channel lined in concrete	Heavy deposits of fine material, extensive bar development; OR recent channelization or dredging evident; or over 80% of banks artificially armored
7. Bank Stability(g)	Upper bank stable, 0-10% of banks with erosional scars and little potential for future problems	Moderately stable. 10-30% of banks with erosional scars, mostly healed over. Slight potential in extreme floods	Moderately unstable. 30-60% of banks with erosional scars and high erosion potential during extreme high flow	Unstable. Many eroded areas. "Raw" areas frequent along straight sections and bends. Side slopes >60° common
8. Embeddedness(h)	Percentage that gravel, cobble, and boulder particles are surrounded by line sediment or flocculent material.			
9. Channel Flow Status(i)	Percentage that water fills available channel			
10. Shading(j)	Percentage of segment that is shaded (duration is considered in scoring). 0% = fully exposed to sunlight all day in summer; 100% = fully and densely shaded all day in summer			
11. Riparian Buffer(k)	Minimum width of vegetated buffer in meters; 50 meters maximum; see back of Habitat Assessment Data Sheet for buffer type and land cover immediately adjacent to buffer			

Habitat Parameter	Optimal (16-20)	Sub-Optimal (11-15)	Marginal (6-10)	Poor (0-5)
12. Aesthetic Rating[l]	Little or no evidence of human refuse present; vegetation visible from stream essentially in a natural state	Human refuse present in minor amounts; and/or channelization present but not readily apparent; and/or minor disturbance of riparian vegetation	Refuse present in moderate amounts; and/or channel-ization readily apparent; and/or moderate disturbance of riparian vegetation	Human refuse abundant and un-sightly: and/or extensive unnatural channelization; and/or nearly complete lack of vegetation
13. Remoteness[m]	Stream segment more than 1/4 mile from nearest road; access difficult and little or no evidence of human activity	Stream segment within 1/4 of but not immediately accessible to roadside access by trail; site with moderately wild character	Stream within 1/4 mile of roadside and accessible by trail; anthropogenic activities readily evident	Segment immediately adjacent to roadside access; visual , olfactory, and/or auditory displeasure experienced

a) **Instream Habitat** Rated based on perceived value of habitat to the fish community. Within each category, higher scores should be assigned to sites with a variety of habitat types and particle sizes. In addition, higher scores should be assigned to sites with a high degree of hypsographic complexity (uneven bottom). In streams where ferric hydroxide is present, instream habitat scores are not lowered unless the precipitate has changed the gross physical nature of the substrate. In streams where substrate types are favorable but flows are so low that fish are essentially precluded from using the habitat, low scores are assigned. If none of the habitat within a segment is useable by fish, a score of zero is assigned.

b) **Epifaunal Substrate** Rated based on the amount and variety of hard, stable substrates usable by benthic macroinvertebrates. Because they inhibit colonization, floculent materials or fine sediments surrounding otherwise good substrates are assigned low scores. Scores are also reduced when substrates are less stable.

c) **Velocity/Depth Diversity** Rated based on the variety of velocity/depth regimes present at a site (slow-shallow, slow-deep, fast-shallow, and fast-deep). As with embeddedness, this metric may result in lower scores in low-gradient streams but will provide a statewide information on the physical habitat found in Maryland streams.

d) **Pool/Glide/Eddy Quality** Rated based on the variety and spatial complexity of slow- or still-water habitat within the sample segment. It should be noted that even in high-gradient segments, functionally important slow-water habitat may exist in the form of larger eddies. Within a category, higher scores are assigned to segments which have undercut banks, woody debris or other types of cover for fish.

e) **Riffle/Run Quality** Rated based on the depth, complexity, and functional importance of riffle/run habitat in the segment, with highest scores assigned to segments dominated by deeper riffle/run areas, stable substrates, and a variety of current velocities.

f) **Channel Alteration** Is a measure of large-scale changes in the shape of the stream channel. Channel alteration includes: concrete channels, artificial embankments, obvious straightening of the natural channel, rip-rap, or other structures, as well as recent bar development. Ratings for this metric are based on the presence of artificial structures as well as the existence, extent, and coarseness of point bars, side bars, and mid-channel bars which indicate the degree of flow fluctuations and substrate stability. Evidence of channelization may sometimes be seen in the form of berms which parallel the stream channel.

g) **Bank Stability** Rated based on the presence/absence of riparian vegetation and other stabilizing bank materials such as boulders and rootwads, and frequency/size of erosional areas. Sites with steep slopes are not penalized if banks are composed solely of stable materials.

h) **Embeddedness** Rated as a percentage based on the fraction of surface area of larger particles that is surrounded by fine sediments on the stream bottom. In low gradient streams with substantial natural deposition, the correlation between embeddedness and fishability or ecological health may be weak or non-existent, but this metric is rated in all streams to provide similar information from all sites statewide.

i) **Channel Flow Status** Rated based on the percentage of the stream channel that has water, with subtractions made for exposed substrates and islands.

j) **Shading** Rated based on estimates of the degree and duration of shading at a site during summer, including any effects of shading caused by landforms.

k) **Riparian Buffer Zone** Based on the size and type of the vegetated riparian buffer zone at the site. Cultivated fields for agriculture which have bare soil to any extent are not considered as riparian buffers. At sites where the buffer width is variable or direct delivery of storm runoff or sediment to the stream is evident or highly likely, the smallest buffer in the segment. (e.g., 0 if parking lot runoff enters directly to the stream) is measured and recorded even though some of the segment may have a well developed buffer. In cases where the riparian zone on one side of the stream slopes away from the stream and there is no direct point of entry for runoff, the buffer on the other side of the stream should be measured and recorded and a comment made in comments section of the data sheet.

l) **Aesthetic Rating** Rated based on the visual appeal of the site and presence/absence of human refuse, with highest scores assigned to stream segments with no human refuse and visually outstanding character.

m) **Remoteness** Rated based on the absence of detectable human activity and difficulty in accessing the segment.

Appendix D: Location and physical habitat data for MBSS sites in the Pocomoke basin, 1997. See Habitat Assessment Guidance Sheet for details.

Stream Name	Latitude	Longitude	Segment Length (m)	Instream Habitat	Epifaunal Substrate	Velocity/ Depth	Pool Quality
Kings Cr.	38.1560	75.6520	75	8	5	6	7
Marumsco Cr.	38.0760	75.6950	74	5	5	6	8
Lorretto Br.	38.2270	75.6650	75	16	11	6	11
South Fork Green Run	38.4310	75.3750	71	14	10	10	10
Green Run	38.4260	75.3660	75	12	10	8	10
Burnt Mill Br.	38.3970	75.3420	75	5	3	6	11
Forest Grove Br.	38.3540	75.4560	74	11	12	4	15
Pocomoke R.	38.3310	75.3260	75	11	10	8	16
Adkins Race	38.3260	75.3620	53	15	14	10	14
Adkins Race	38.3220	75.3570	71	17	15	10	15
Adkins Race	38.3250	75.3600	50	19	18	10	16
Truitt Br.	38.3510	75.3670	70	1	1	2	2
Burnt Mill Br.	38.4020	75.3700	75	10	9	10	13
Burnt Mill Br.	38.4020	75.3580	75	10	6	11	15
Murray Br.	38.4020	75.3500	75	10	5	12	10
Campbell Ditch	38.3800	75.4260	75	4	3	2	2
Duncan Ditch	38.3030	75.3700	73	6	5	5	6
Pocomoke R.	38.4060	75.3180	75	14	14	6	11
Pocomoke R.	38.4020	75.3180	75	12	11	5	6
Pocomoke R.	38.4200	75.3250	75	9	11	8	11
Pocomoke R.	38.3830	75.3290	75	10	10	5	8
Pocomoke R.	38.4110	75.3200	75	12	11	5	9
Jones Ditch	38.0930	75.4640	66	13	11	9	15
Pocomoke R.	38.3730	75.3240	75	8	8	7	12
Pocomoke R.	38.4300	75.3340	75	7	6	8	7
Pocomoke R.	38.4250	75.3320	75	14	12	10	14
Millville Cr.	38.2480	75.4890	62	17	16	2	18
N. Fork To Green Run	38.4370	75.3500	75	16	13	6	15

Appendix D: Location and physical habitat data for MBSS sites in the Pocomoke basin, 1997. See Habitat Assessment Guidance Sheet for details.

Stream Name	Latitude	Longitude	Riffle Quality	Channel Alteration	Bank Stability	Percent Embeddedness	Channel Flow (%)
Kings Cr.	38.1560	75.6520	4	10	11	99	90
Marumsco Cr.	38.0760	75.6950	3	5	10	100	60
Lorretto Br.	38.2270	75.6650	6	11	16	100	50
South Fork Green Run	38.4310	75.3750	11	8	15	100	50
Green Run	38.4260	75.3660	11	5	17	100	75
Burnt Mill Br.	38.3970	75.3420	11	5	16	100	100
Forest Grove Br.	38.3540	75.4560	0	6	17	100	40
Pocomoke R.	38.3310	75.3260	16	5	10	100	95
Adkins Race	38.3260	75.3620	10	10	15	100	85
Adkins Race	38.3220	75.3570	16	11	19	100	85
Adkins Race	38.3250	75.3600	16	11	15	100	90
Truitt Br.	38.3510	75.3670	3	0	1	100	95
Burnt Mill Br.	38.4020	75.3700	11	9	8	100	95
Burnt Mill Br.	38.4020	75.3580	16	5	11	100	95
Murray Br.	38.4020	75.3500	13	2	13	100	90
Campbell Ditch	38.3800	75.4260	0	5	11	100	95
Duncan Ditch	38.3030	75.3700	8	5	11	100	80
Pocomoke R.	38.4060	75.3180	11	7	10	100	95
Pocomoke R.	38.4020	75.3180	6	5	10	100	90
Pocomoke R.	38.4200	75.3250	13	11	15	100	98
Pocomoke R.	38.3830	75.3290	13	7	7	100	85
Pocomoke R.	38.4110	75.3200	11	8	11	100	97
Jones Ditch	38.0930	75.4640	8	10	11	100	75
Pocomoke R.	38.3730	75.3240	16	4	5	100	85
Pocomoke R.	38.4300	75.3340	11	8	11	100	70
Pocomoke R.	38.4250	75.3320	16	5	5	100	90
Millville Cr.	38.2480	75.4890	0	16	16	100	90
N. Fork To Green Run	38.4370	75.3500	0	13	16	100	98

Appendix D: Location and physical habitat data for MBSS sites in the Pocomoke basin, 1997. See Habitat Assessment Guidance Sheet for details.

Stream Name	Latitude	Longitude	Percent Shading	Riparian Width (m)	Aesthetic Rating	Max. Depth (cm)	Stream Gradient
Kings Cr.	38.1560	75.6520	90	50	14	44	0.20
Marumsco Cr.	38.0760	75.6950	80	50	17	29	0.20
Lorretto Br.	38.2270	75.6650	20	11	15	79	0.20
South Fork Green Run	38.4310	75.3750	30	10	11	34	0.10
Green Run	38.4260	75.3660	20	3	10	38	0.10
Burnt Mill Br.	38.3970	75.3420	10	0	11	70	0.10
Forest Grove Br.	38.3540	75.4560	75	30	15	55	0.10
Pocomoke R.	38.3310	75.3260	65	50	11	200	0.20
Adkins Race	38.3260	75.3620	75	50	15	67	0.10
Adkins Race	38.3220	75.3570	70	50	16	73	0.10
Adkins Race	38.3250	75.3600	70	50	16	79	0.20
Truitt Br.	38.3510	75.3670	40	0	1	10	0.20
Burnt Mill Br.	38.4020	75.3700	10	10	15	55	0.20
Burnt Mill Br.	38.4020	75.3580	20	0	11	79	0.30
Murray Br.	38.4020	75.3500	25	30	15	54	0.10
Campbell Ditch	38.3800	75.4260	40	0	5	32	0.10
Duncan Ditch	38.3030	75.3700	85	23	17	43	0.10
Pocomoke R.	38.4060	75.3180	60	5	17	61	0.20
Pocomoke R.	38.4020	75.3180	65	3	17	44	0.20
Pocomoke R.	38.4200	75.3250	80	50	15	110	0.20
Pocomoke R.	38.3830	75.3290	75	30	14	34	0.20
Pocomoke R.	38.4110	75.3200	70	50	12	44	0.30
Jones Ditch	38.0930	75.4640	80	35	16	72	0.10
Pocomoke R.	38.3730	75.3240	75	50	13	84	0.20
Pocomoke R.	38.4300	75.3340	85	50	12	34	0.20
Pocomoke R.	38.4250	75.3320	80	50	16	117	0.20
Millville Cr.	38.2480	75.4890	80	23	10	68	0.10
N. Fork To Green Run	38.4370	75.3500	20	3	17	85	0.20

Appendix D: Location and physical habitat data for MBSS sites in the Pocomoke basin, 1997. See Habitat Assessment Guidance Sheet for details.

Stream Name	Latitude	Longitude	Woody Debris	Number of Rootwads
Kings Cr.	38.1560	75.6520	2	3
Marumsco Cr.	38.0760	75.6950	2	0
Lorretto Br.	38.2270	75.6650	1	0
South Fork Green Run	38.4310	75.3750	0	0
Green Run	38.4260	75.3660	0	0
Burnt Mill Br.	38.3970	75.3420	2	0
Forest Grove Br.	38.3540	75.4560	2	0
Pocomoke R.	38.3310	75.3260	2	0
Adkins Race	38.3260	75.3620	7	3
Adkins Race	38.3220	75.3570	9	6
Adkins Race	38.3250	75.3600	13	5
Truitt Br.	38.3510	75.3670	0	0
Burnt Mill Br.	38.4020	75.3700	0	0
Burnt Mill Br.	38.4020	75.3580	1	0
Murray Br.	38.4020	75.3500	0	0
Campbell Ditch	38.3800	75.4260	0	0
Duncan Ditch	38.3030	75.3700	2	3
Pocomoke R.	38.4060	75.3180	5	7
Pocomoke R.	38.4020	75.3180	5	0
Pocomoke R.	38.4200	75.3250	4	4
Pocomoke R.	38.3830	75.3290	2	0
Pocomoke R.	38.4110	75.3200	7	5
Jones Ditch	38.0930	75.4640	5	10
Pocomoke R.	38.3730	75.3240	4	1
Pocomoke R.	38.4300	75.3340	1	0
Pocomoke R.	38.4250	75.3320	8	3
Millville Cr.	38.2480	75.4890	13	10
N. Fork To Green Run	38.4370	75.3500	0	0

ECOLOGY AND DISTRIBUTION OF FISH SPECIES COLLECTED IN NON-TIDAL STREAMS OF MARYLAND

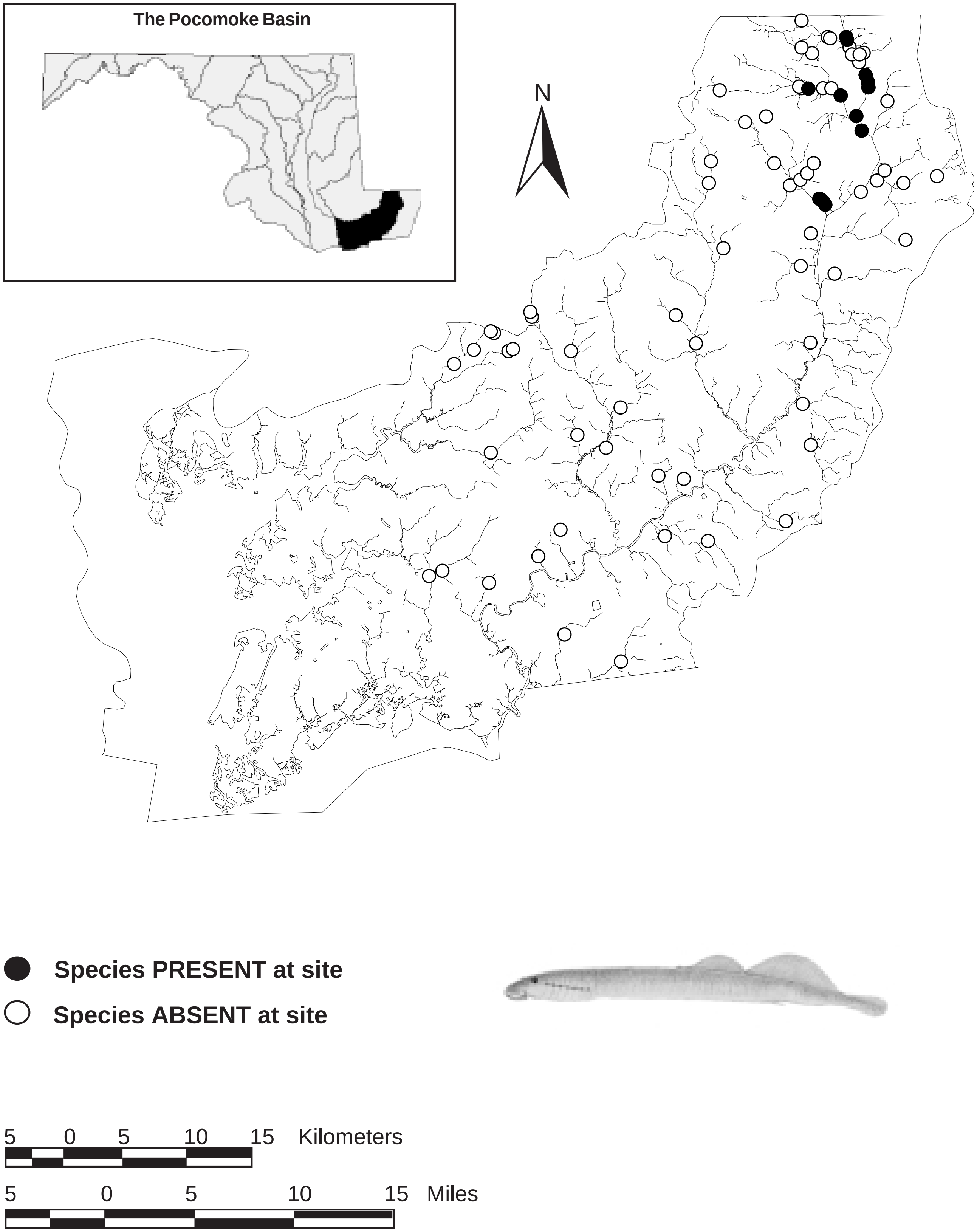
The species descriptions (Jenkins and Burkhead 1994, Rohde *et al*. 1994) and distributional maps which follow (**Figures E1-E36**) include those fish species collected during both random and non-random sampling efforts as part of the 1994 and 1997 MBSS sampling in Maryland.

Common Name	Family	Tolerance	Feeding Group	Distribution Map	Interesting Facts
Least brook lamprey	Lamprey	Intolerant	Filter Feeder	E-1	The larval stage of this species may last a decade or more, but the adult stage is short with death occurring after spawning.
Longnose gar	Gars	Moderate	Top Predator	E-2	This spear shaped, bony-armored ambush predator feeds on other fish, as it has for thousands of years.
American eel	Eel	Tolerant	Generalist	E-3	Although most of their life is spent in freshwater streams (up to 20 years or more), adults become silver in color and journey to the Sargasso sea to spawn (catadromous).
Chain pickerel	Pike	Moderate	Top Predator	E-4	This ambush predator feeds almost exclusively on other fish.
Redfin pickerel	Pike	Moderate	Top Predator	E-5	This member of the pike family is able to survive in small streams and ditches with extremely low dissolved oxygen.
Eastern mudminnow	Mudminnow	Tolerant	Invertivore	E-6	As the name implies, this species buries itself into the mud during the day and is nocturnally active.
Common carp	Minnow	Tolerant	Omnivore	E-7	This minnow is tolerant of many environmental conditions and can survive in highly degraded habitat.
Eastern silvery minnow	Minnow	Moderate	Algivore	E-8	An inhabitant of flat water areas, including tidal freshwater, this species is tolerant of low dissolved oxygen and siltation.
Golden shiner	Minnow	Tolerant	Omnivore	E-9	This species is a favorite food of largemouth bass. It has been transported throughout the United States as a result of bait bucket introductions.

Common Name	Family	Tolerance	Feeding Group	Distribution Map	Interesting Facts
Satinfin shiner	Minnow	Moderate	Invertivore	E-10	This species is considered a good aquarium fish because of its active nature and ready acceptance of dried food.
Swallowtail shiner	Minnow	Moderate	Invertivore	E-11	This species seems to use both minnow and sunfish nests for spawning, unlike other minnows which only spawn on other minnow nests.
Creek chubsucker	Sucker	Moderate	Invertivore	E-12	This species lacks a lateral line and therefore is easily distinguishable from other suckers in Maryland.
Brown bullhead	Catfish	Tolerant	Omnivore	E-13	Although considered native to Maryland, this species has been widely introduced throughout the United States to provide fishing opportunities.
Channel catfish	Catfish	Moderate	Omnivore	E-14	This large river and lake species is not native to Maryland.
Margined madtom	Catfish	Moderate	Invertivore	E-15	This is a highly nocturnal species which requires hiding places to thrive. The spines of margined madtoms are venomous and can inflict considerable pain if handled incorrectly.
Tadpole madtom	Catfish	Moderate	Invertivore	E-16	This species occurs in warm streams and rivers in the lowlands of eastern and central North America. As with other madtoms, the spines are mildly venomous.
White catfish	Catfish	Moderate	Omnivore	E-17	A Chesapeake Bay native, this species has been widely displaced by channel catfish, an introduced species.
Yellow bullhead	Catfish	Tolerant	Omnivore	E-18	Although bullheads are considered bottom feeders, when given the opportunity they are quite capable of catching and eating fish such as minnows and sunfish.
Pirate perch	Pirate perch	Moderate	Invertivore	E-19	The only living member of its family, this species has its urogenital openings and anus on its throat.
Mummichog	Killifish	Moderate	Invertivore	E-20	Although freshwater populations exist, this species is more commonly found in estuaries and is known to tolerate salinities up to 32 parts per thousand.

Common Name	Family	Tolerance	Feeding Group	Distribution Map	Interesting Facts
Eastern Mosquitofish	Topminnow	Moderate	Invertivore	E-21	As the name implies, this species has been known to control mosquito populations by feeding on pupal and larval stages.
White perch	Temperate bass	Moderate	Invertivore	E-22	This species spawns from late March through May, migrating from the lower portions of the Chesapeake Bay upstream to freshwater (semi-anadromous).
Black crappie	Sunfish	Moderate	Generalist	E-23	Found in swamps, ponds, lakes, reservoirs, and slack water of low to moderate-gradient streams and rivers, this species is usually found near aquatic vegetation, fallen trees, stumps, and other structure. Fallen trees are often placed around draw-down zones in reservoirs to attract this species.
Bluegill	Sunfish	Tolerant	Invertivore	E-24	This species has been widely introduced throughout the United States, and has flourished as a result of its tolerance to a variety of conditions.
Bluespotted sunfish	Sunfish	Moderate	Invertivore	E-25	This species is distinguished by long, spotted fins and iridescent silver to blue body spots contrasting with dark and other hues. Because of its small size and timid character, this Maryland native is often out competed by introduces sunfish such as largemouth bass and bluegill.
Banded sunfish	Sunfish	Moderate	Invertivore	E-26	This sunfish is known to live in streams with pH values of less than 4 (under the lethal limit of most species). However, this species is out- competed and preyed upon by larger members of the sunfish family.
Green sunfish	Sunfish	Tolerant	Generalist	E-27	This species is intolerant of low pH streams, but tolerant of many other types of stress. The lowest pH stream site in the basin where this sunfish was collected at was 7.1.
Largemouth bass	Sunfish	Moderate	Top Predator	E-28	This species is considered the most popular gamefish in the United States and has been known to reach weights of over 20 pounds.
Mud sunfish	Sunfish	Moderate	Invertivore	E-29	As the name implies, this nocturnal, secretive sunfish prefers sluggish, muddy pools and swamps. This species is listed as rare in Maryland.
Pumpkinseed	Sunfish	Moderate	Invertivore	E-30	This sunfish is tolerant of darkly-stained acidic waters and is a regular visitor to brackish waters.

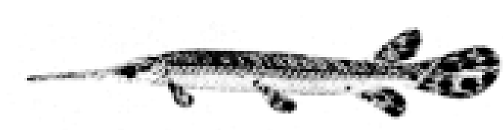
Common Name	Family	Tolerance	Feeding Group	Distribution Map	Interesting Facts
Redbreast sunfish	Sunfish	Moderate	Generalist	E-31	Often found with smallmouth bass and other "cool water" species, this sunfish has been found in water warmer than 100 ^{o}F.
Glassy darter	Perch	Intolerant	Insectivore	E-32	Endangered in the state of Maryland, this darter is named for its translucent body.
Shield darter	Perch	Intolerant	Insectivore	E-33	This bottom-dwelling species occupies warm streams and rivers and avoids moderately to heavily silted areas.
Swamp darter	Perch	Intolerant	Invertivore	E-34	As the name implies, this darter is found in swamps and sluggish creeks with mud or detritus covered beds.
Tessellated darter	Perch	Moderate	Invertivore	E-35	The male tessellated darter has a curious behavior of frequently caring for nests containing eggs that it did not fertilize.
Yellow perch	Perch	Moderate	Generalist	E-36	The yellow perch population in Chesapeake Bay is unique because it winters in areas of moderate salinity; all other populations spend their entire life cycle in freshwater.



Least brook lamprey distribution in the Pocomoke basin, 1994 and 1997.

● **Species PRESENT at site**

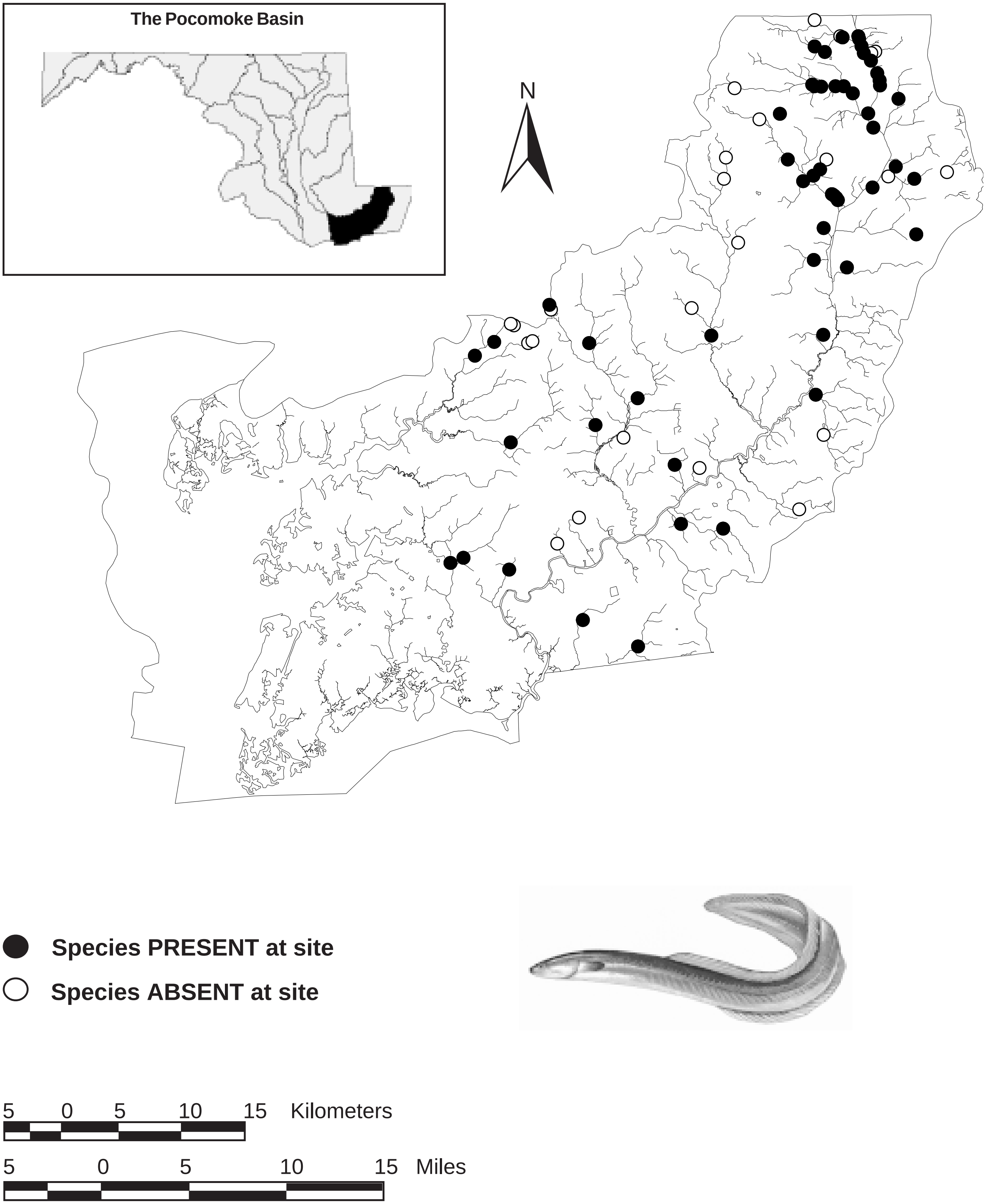
○ **Species ABSENT at site**



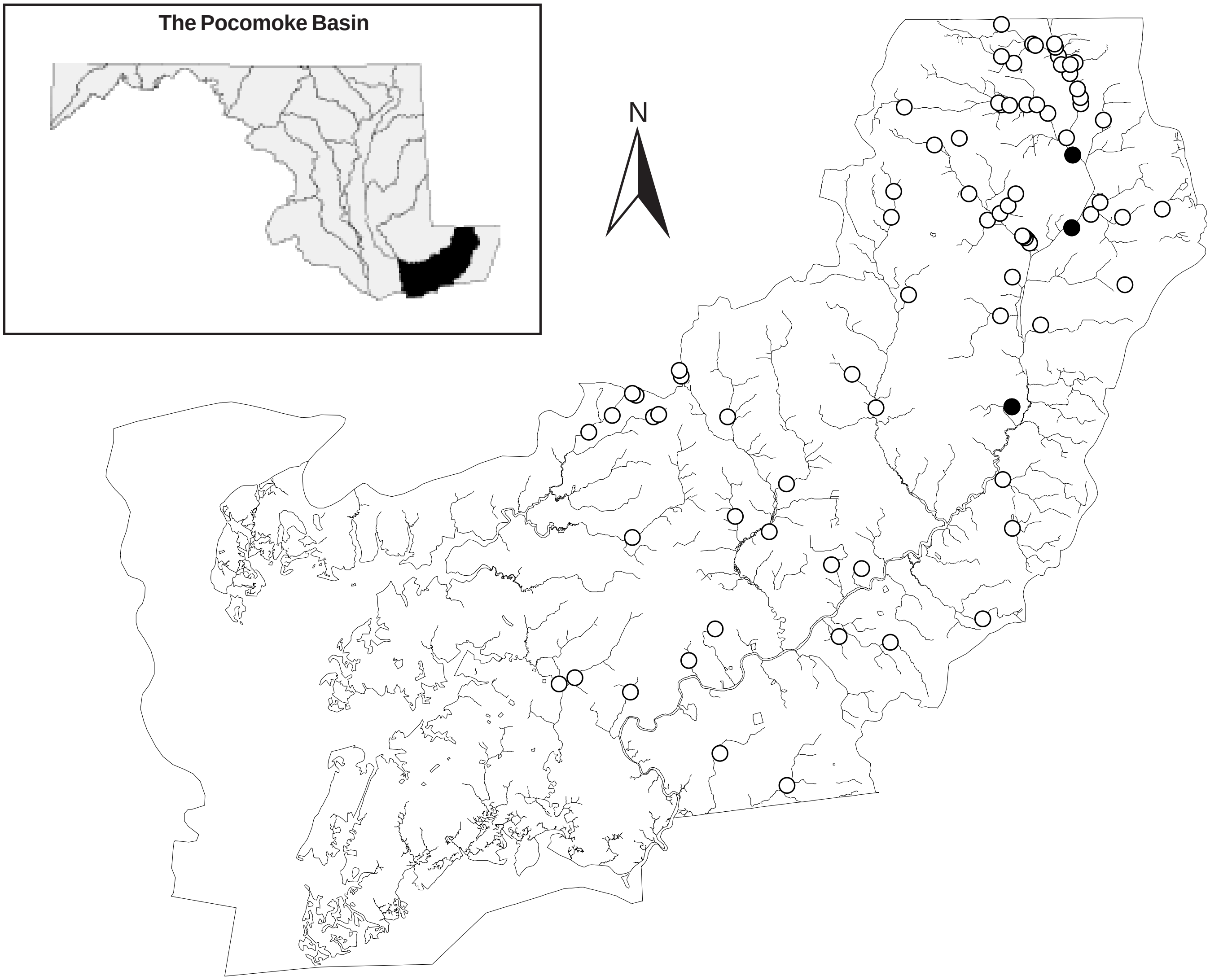
5 0 5 10 15 Kilometers

5 0 5 10 15 Miles

Longnose gar distribution in the Pocomoke basin, 1994 and 1997.



American eel distribution in the Pocomoke basin, 1994 and 1997.



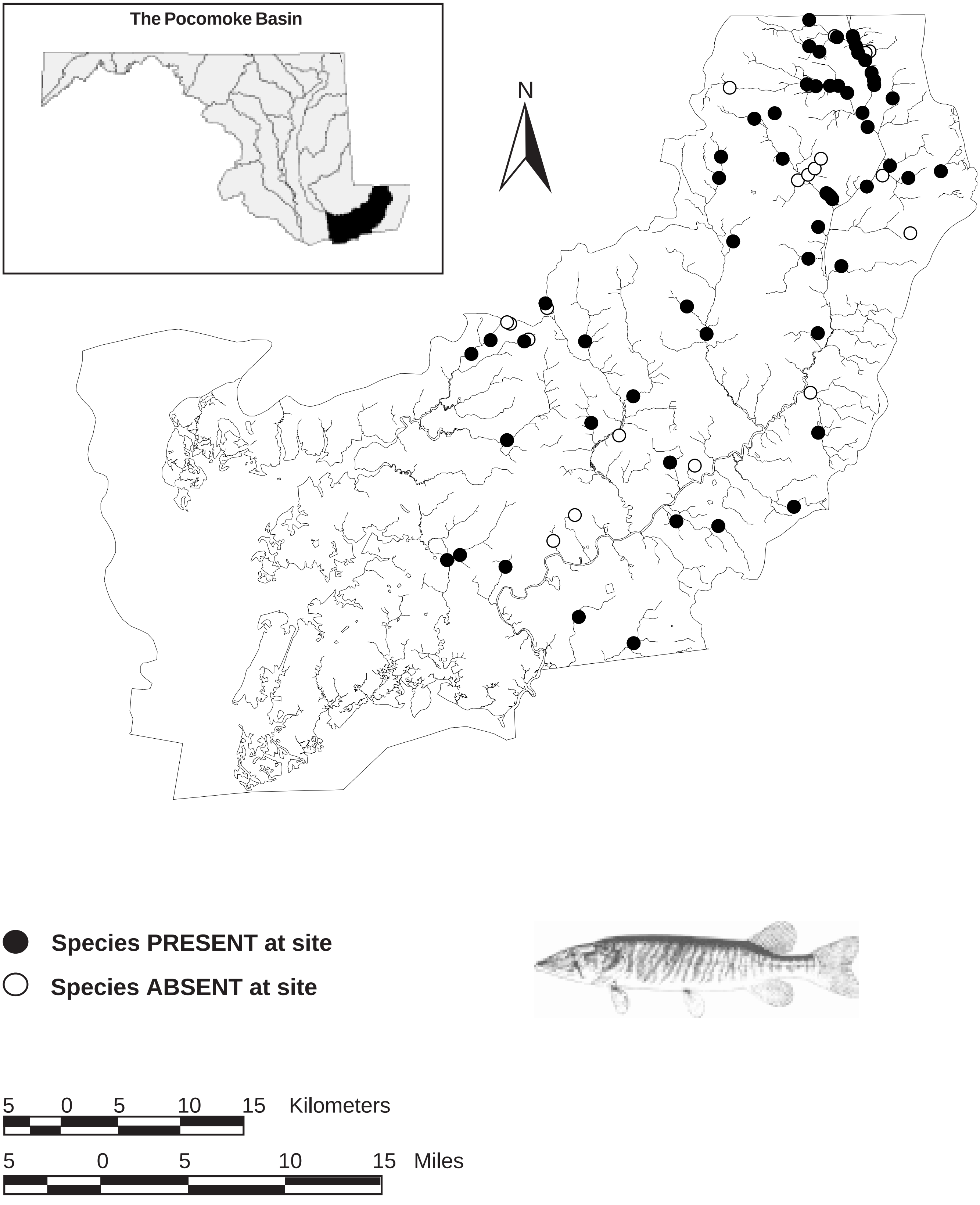
● **Species PRESENT at site**

○ **Species ABSENT at site**

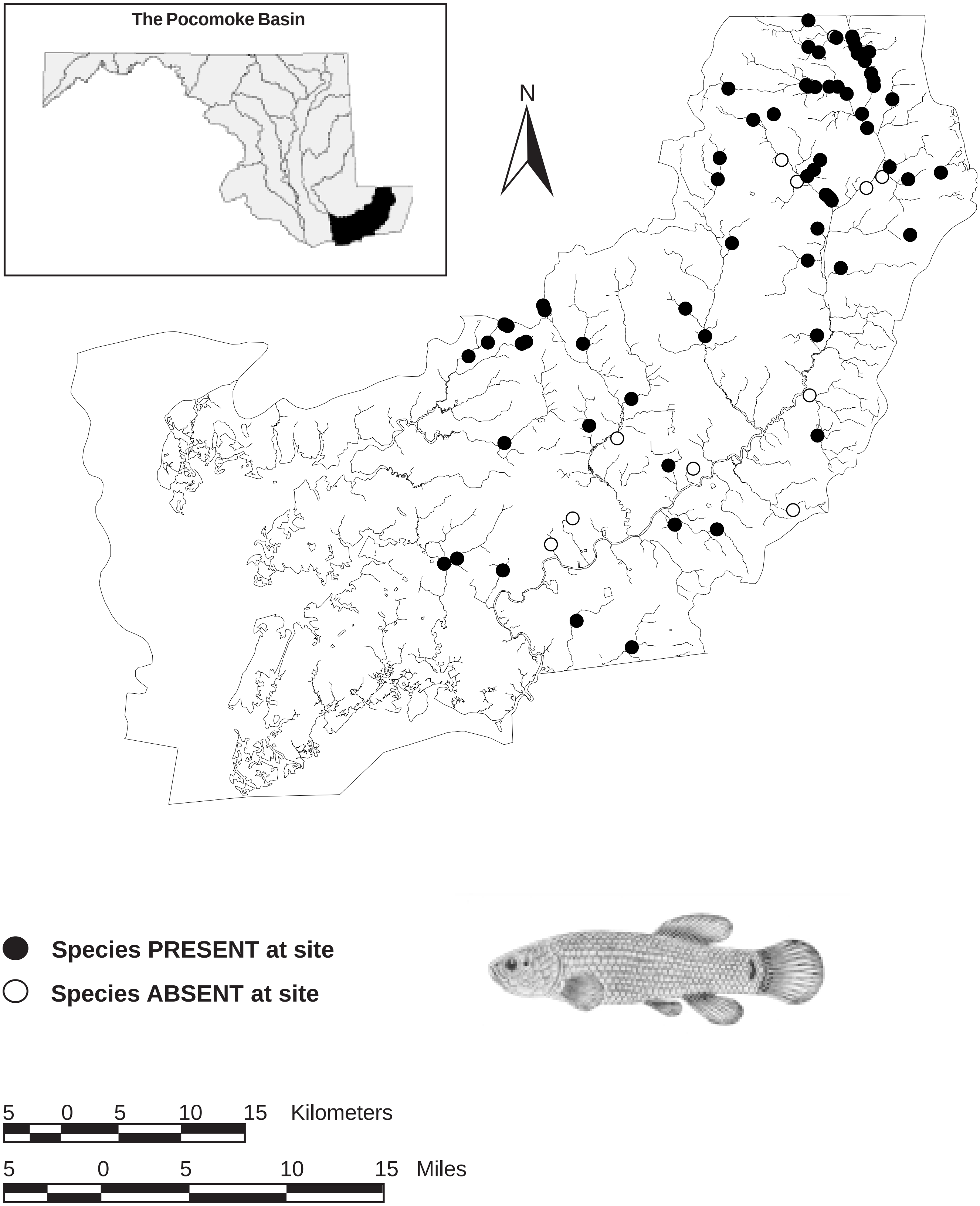
5 0 5 10 15 Kilometers

5 0 5 10 15 Miles

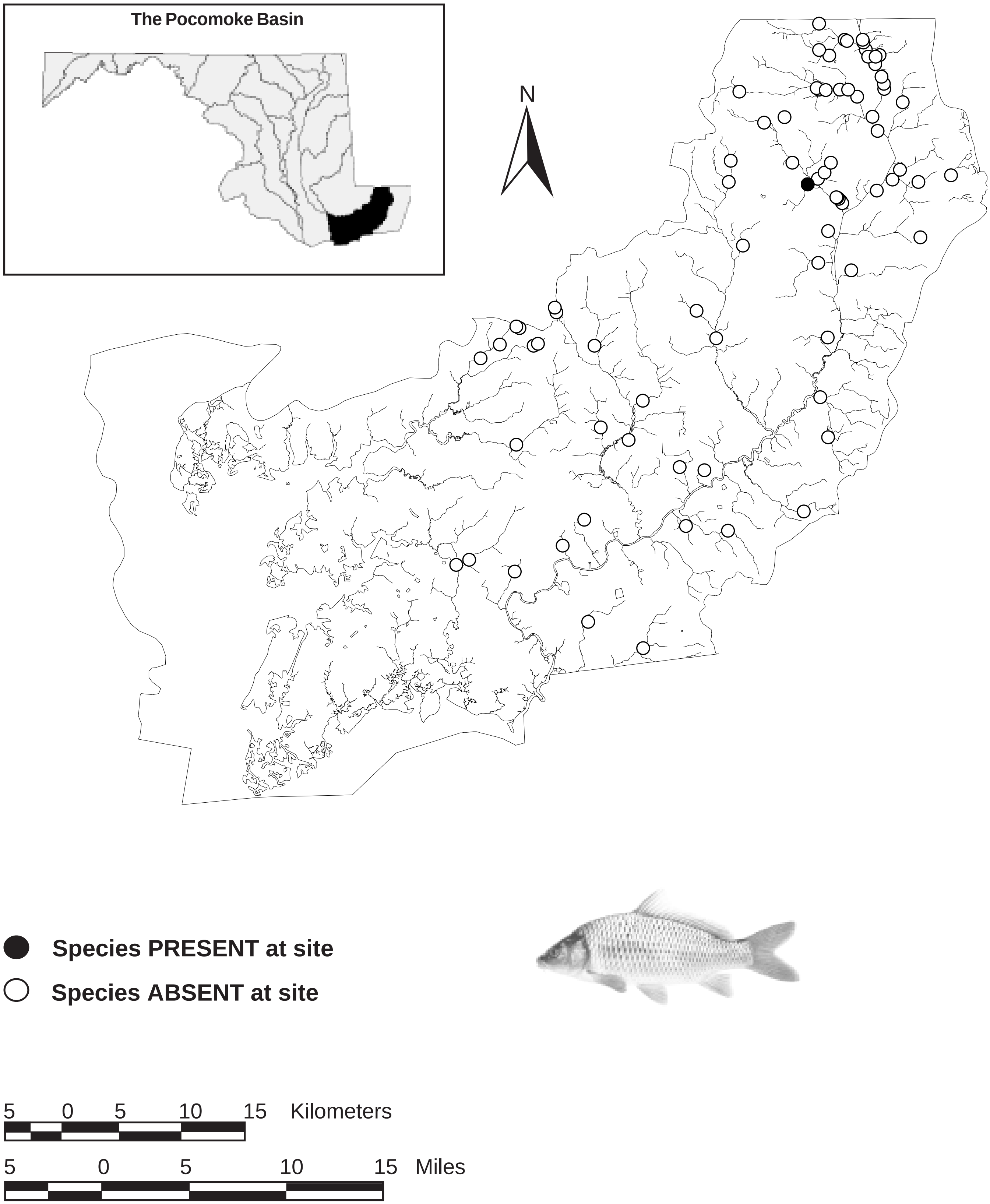
Chain pickerel distribution in the Pocomoke basin, 1994 and 1997.



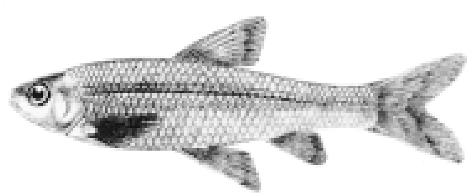
Redfin pickerel distribution in the Pocomoke basin, 1994 and 1997.



Eastern mudminnow distribution in the Pocomoke basin, 1994 and 1997.



Common carp distribution in the Pocomoke basin, 1994 and 1997.



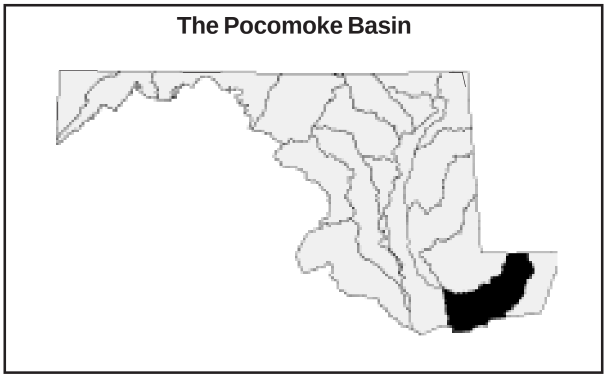
Species PRESENT at site

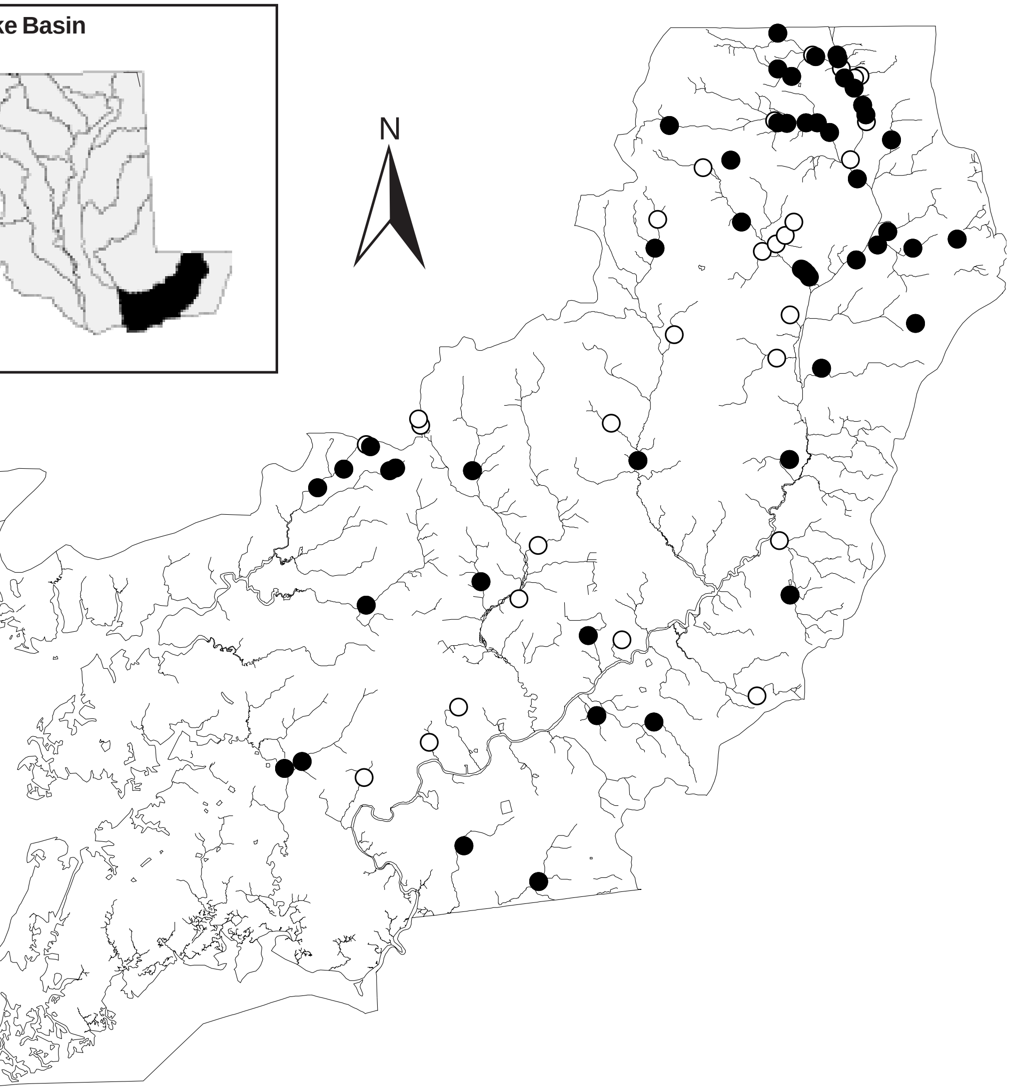
Species ABSENT at site

5 0 5 10 15 Kilometers

5 0 5 10 15 Miles

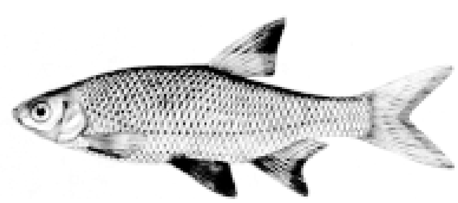
Eastern silvery minnow distribution in the Pocomoke basin, 1994 and 1997.

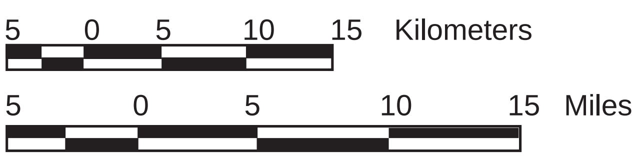




Species PRESENT at site

Species ABSENT at site

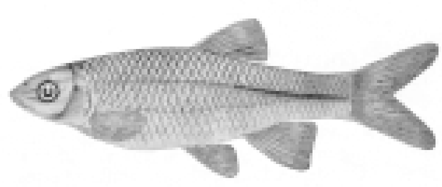




Golden shiner distribution in the Pocomoke basin, 1994 and 1997.

● **Species PRESENT at site**

○ **Species ABSENT at site**



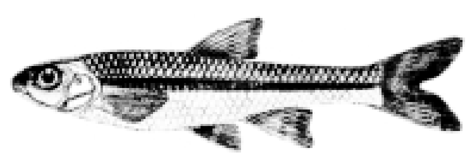
5 0 5 10 15 Kilometers

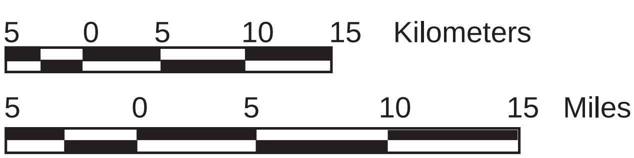
5 0 5 10 15 Miles

Satinfin shiner distribution in the Pocomoke basin, 1994 and 1997.

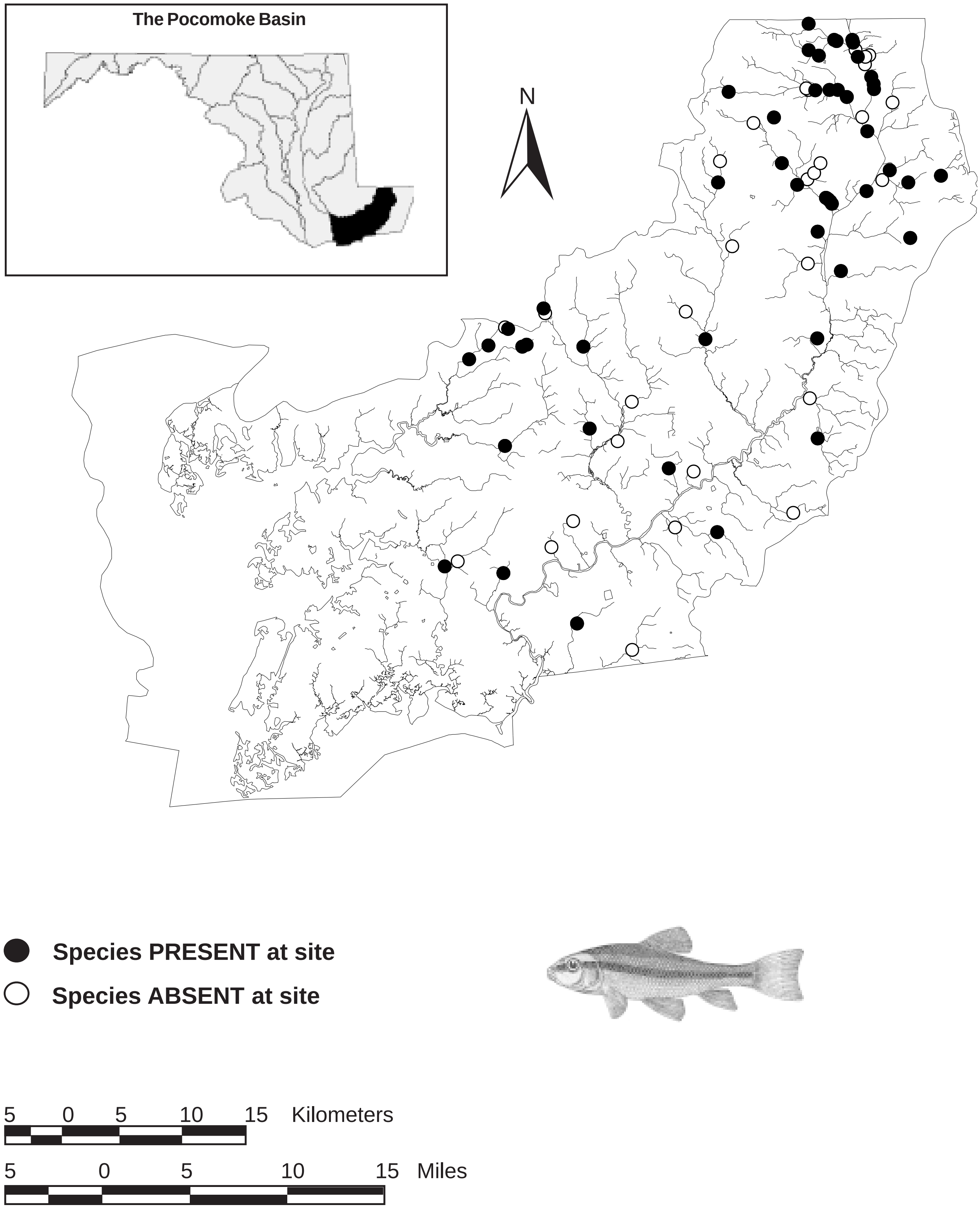
Species PRESENT at site

Species ABSENT at site

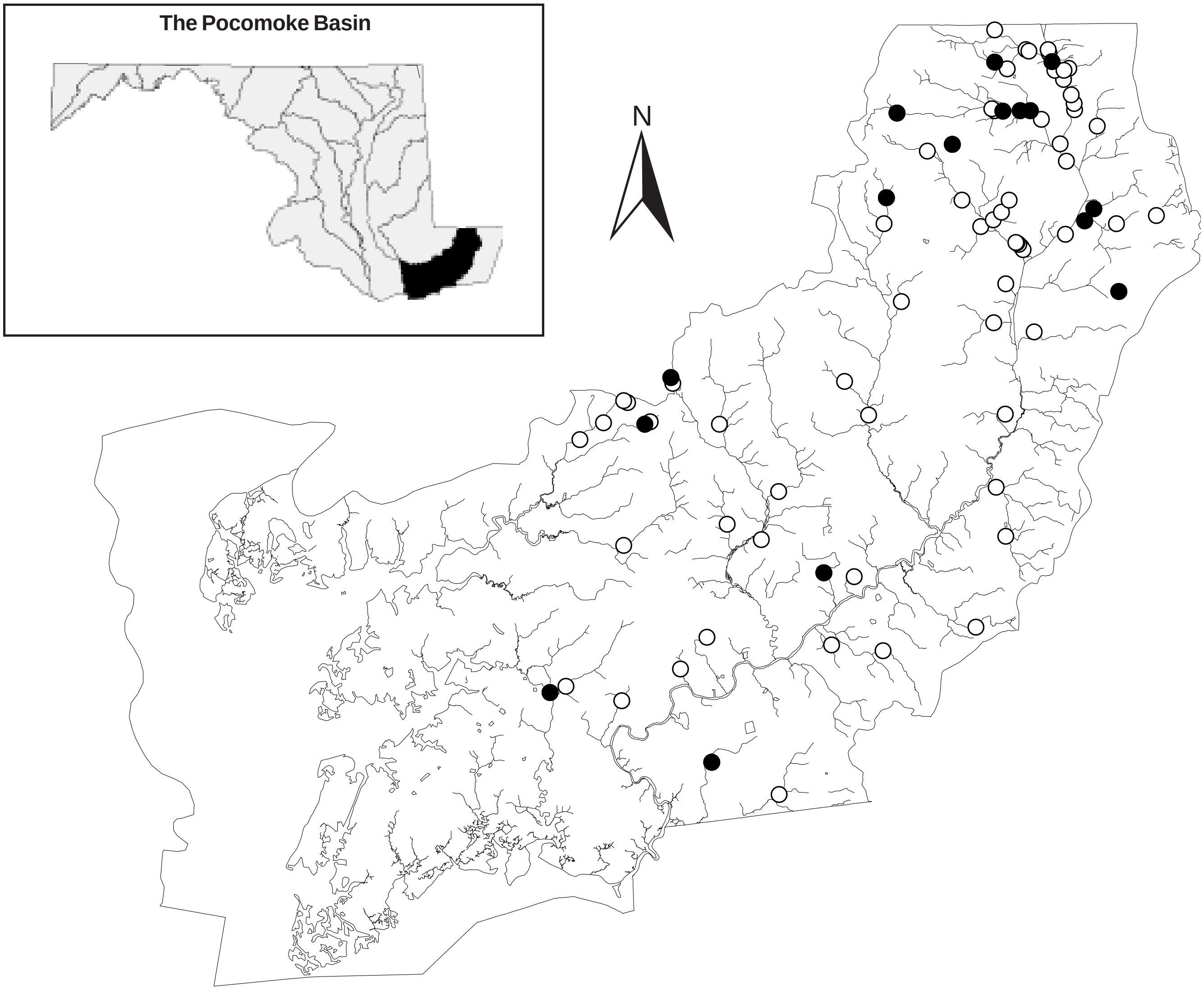




Swallowtail shiner distribution in the Pocomoke basin, 1994 and 1997.

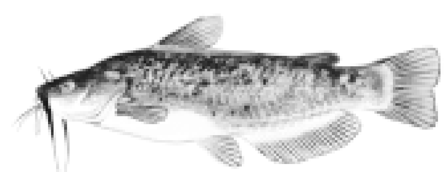


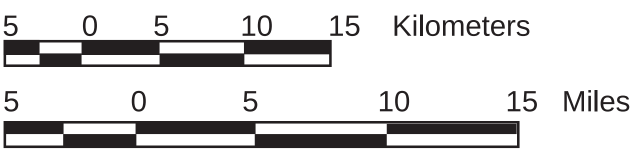
Creek chubsucker distribution in the Pocomoke basin, 1994 and 1997.



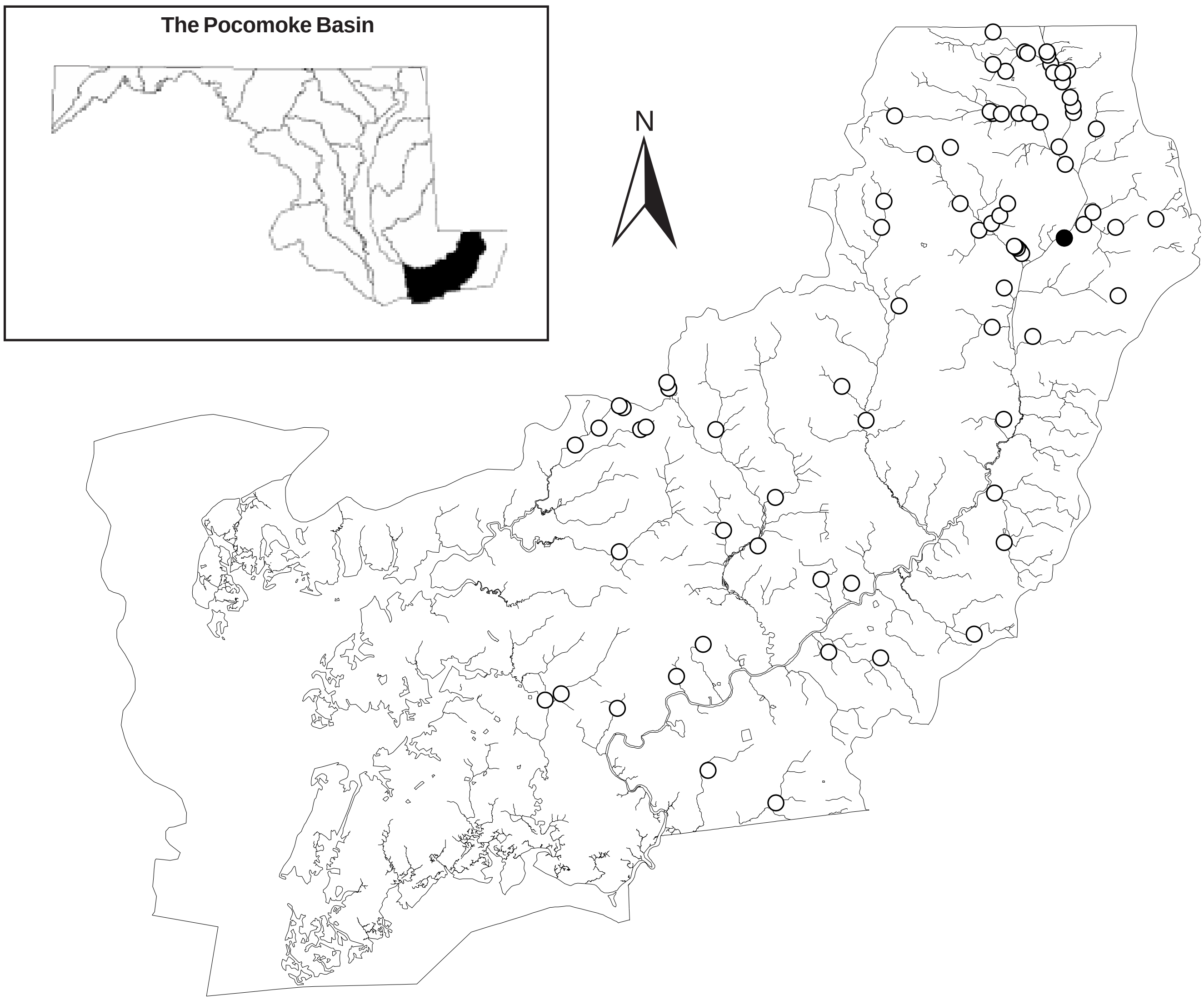
● **Species PRESENT at site**

○ **Species ABSENT at site**



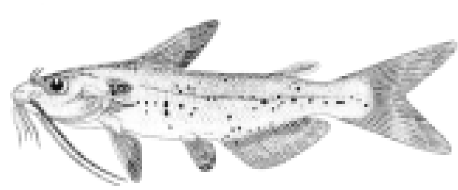


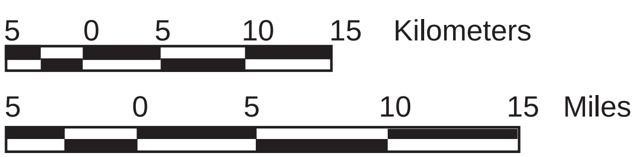
Brown bullhead distribution in the Pocomoke basin, 1994 and 1997.



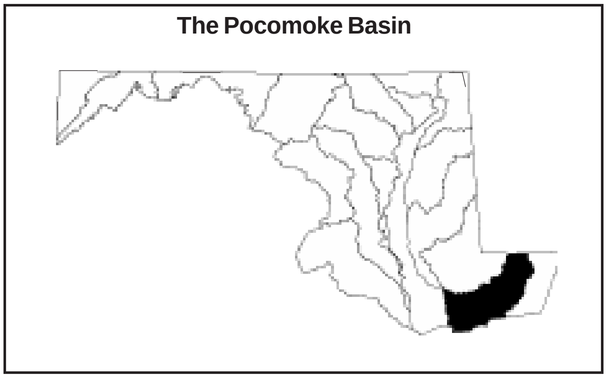
● **Species PRESENT at site**

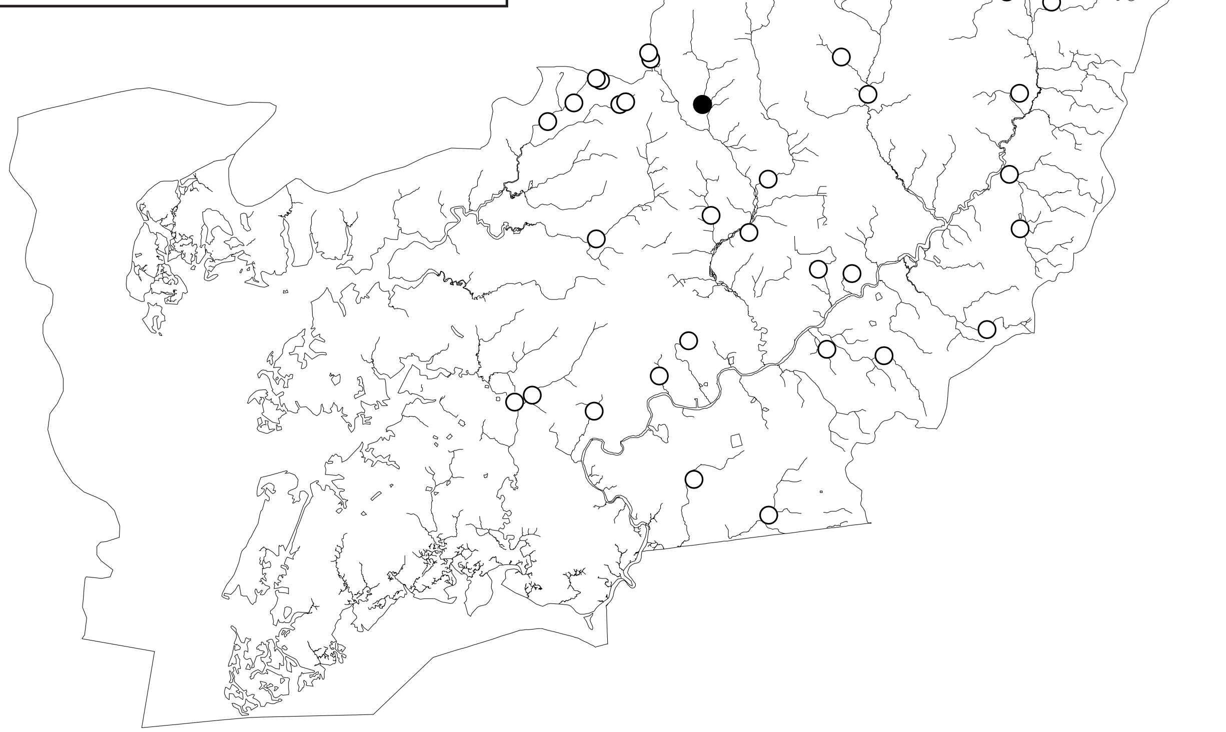
○ **Species ABSENT at site**





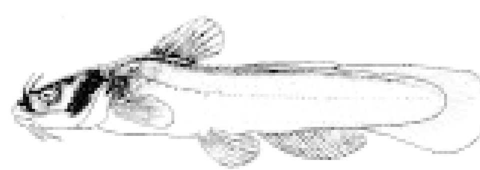
Channel catfish distribution in the Pocomoke basin, 1994 and 1997.

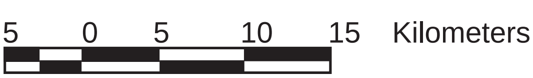




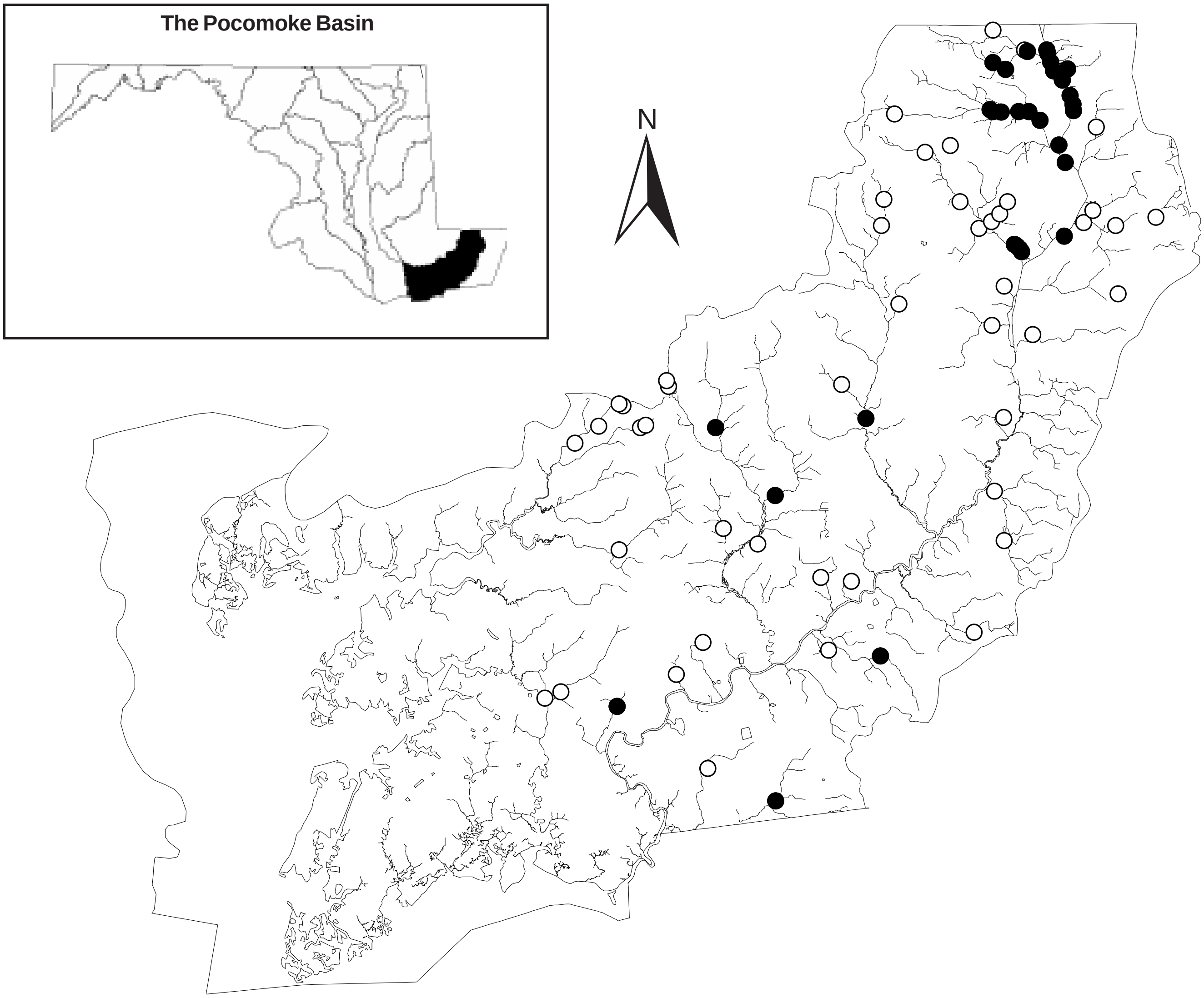
Species PRESENT at site

Species ABSENT at site



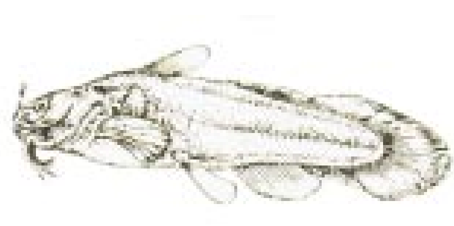


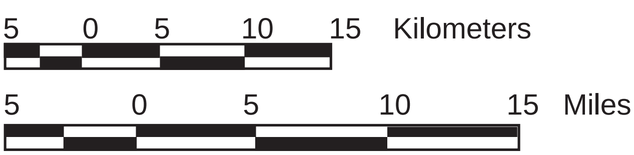
Margined madtom distribution in the Pocomoke basin, 1994 and 1997.



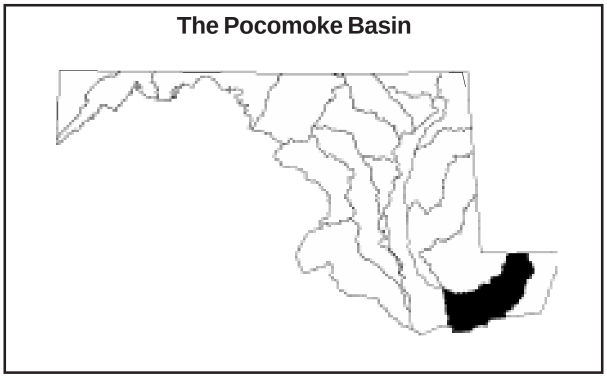
● Species PRESENT at site

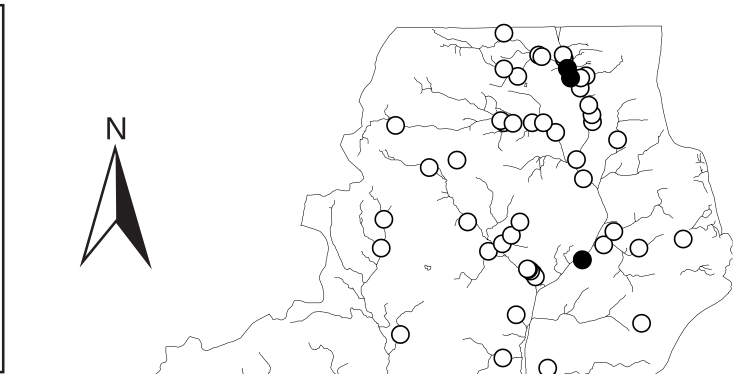
○ Species ABSENT at site

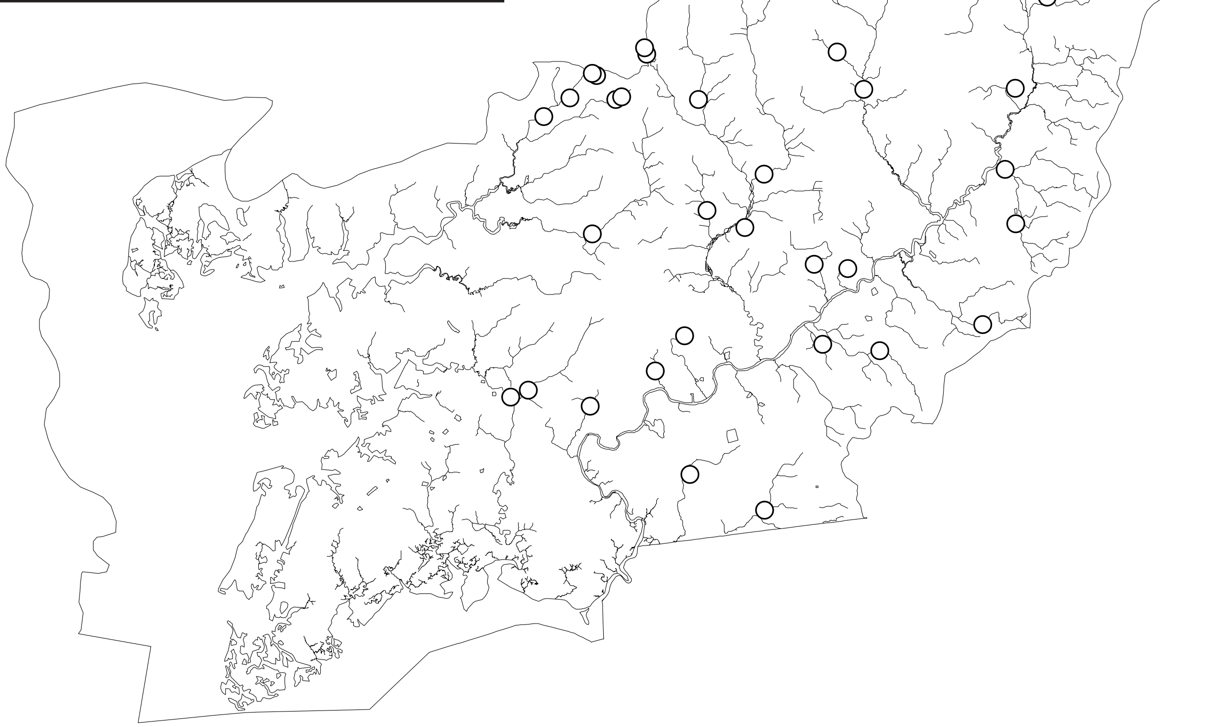




Tadpole madtom distribution in the Pocomoke basin, 1994 and 1997.

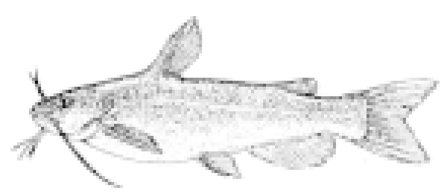






● **Species PRESENT at site**

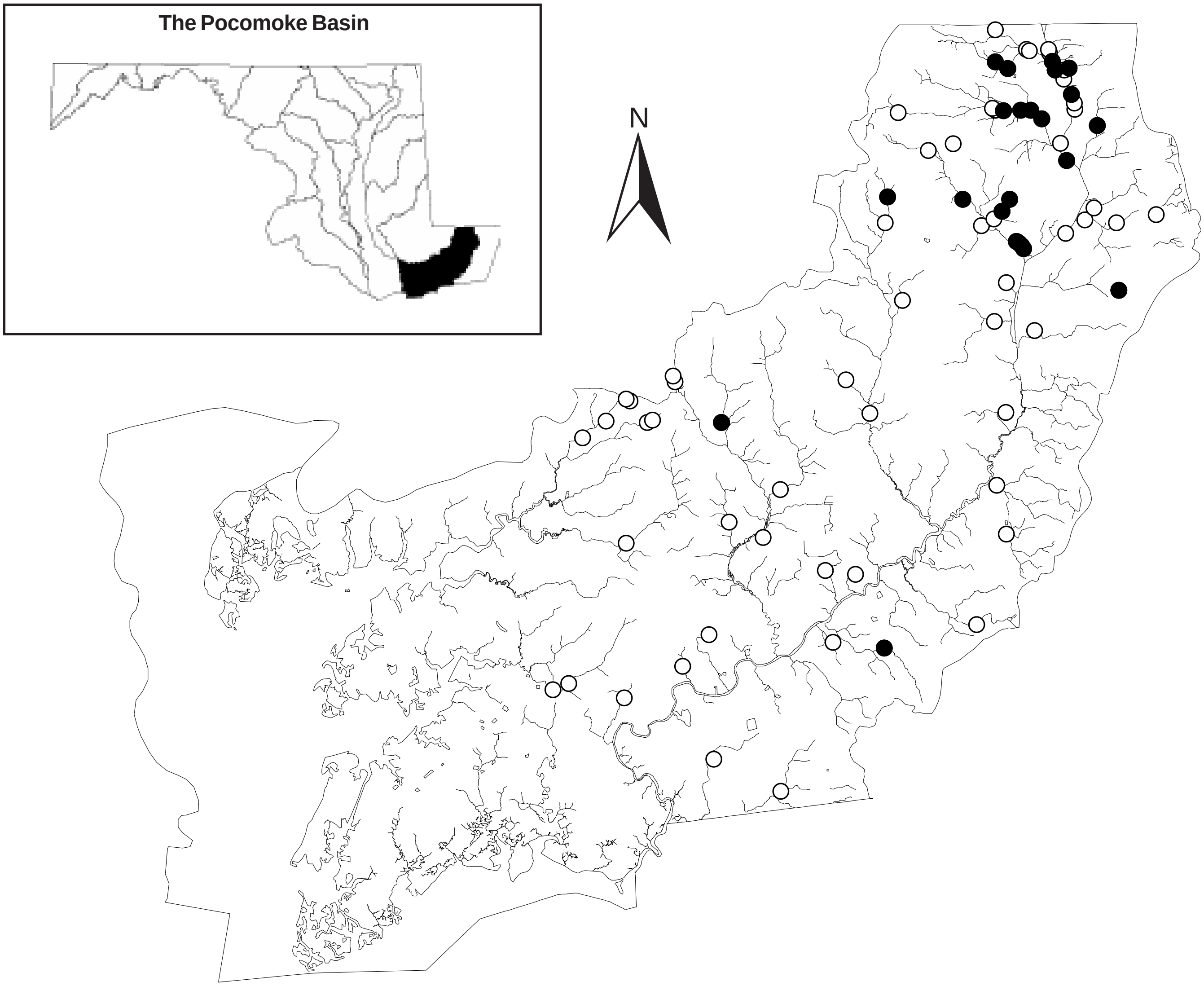
○ **Species ABSENT at site**



5 0 5 10 15 Kilometers

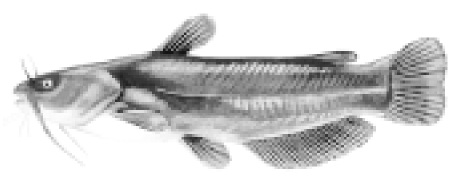
5 0 5 10 15 Miles

White catfish distribution in the Pocomoke basin, 1994 and 1997.



● **Species PRESENT at site**

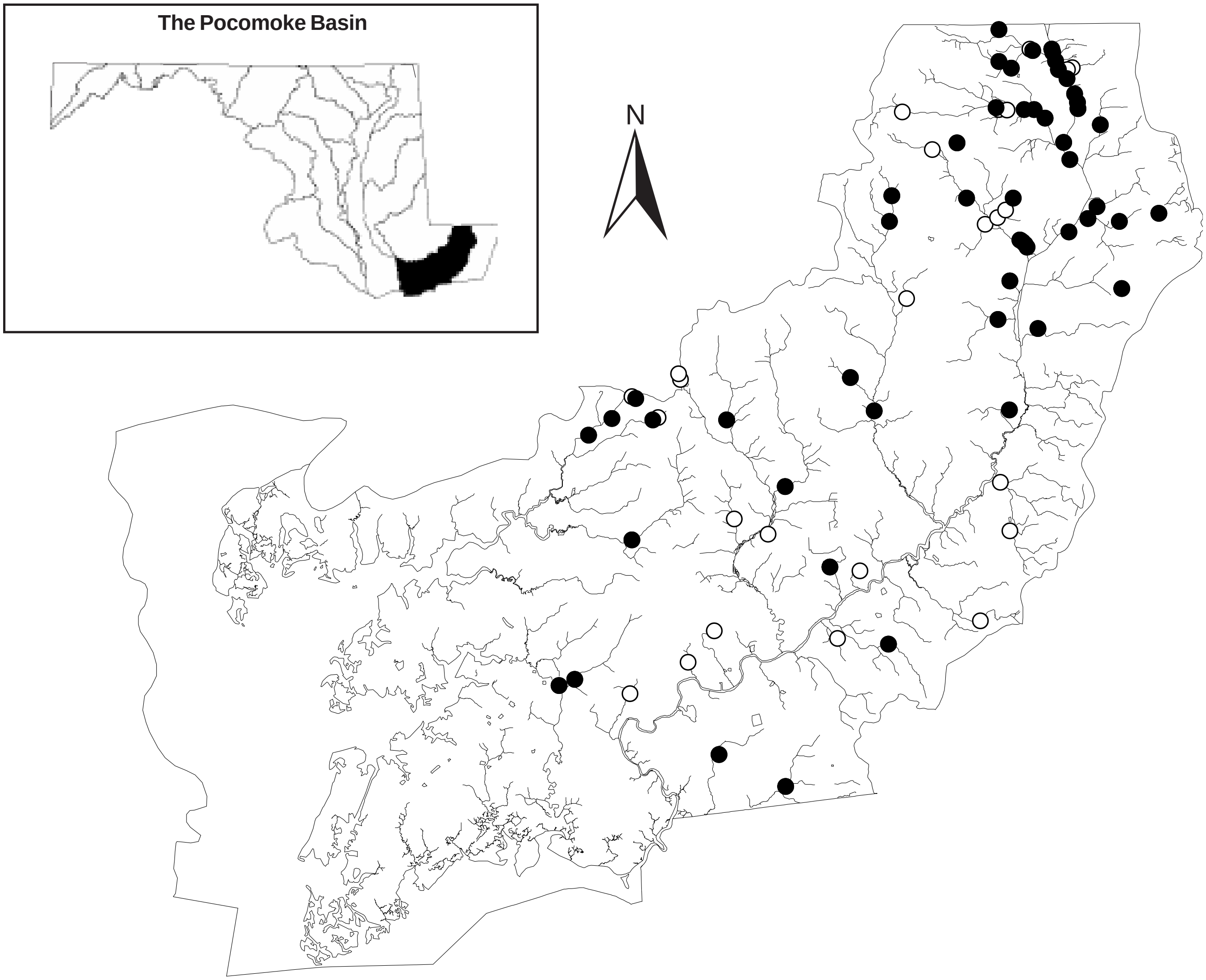
○ **Species ABSENT at site**



5 0 5 10 15 Kilometers

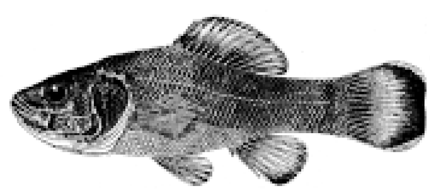
5 0 5 10 15 Miles

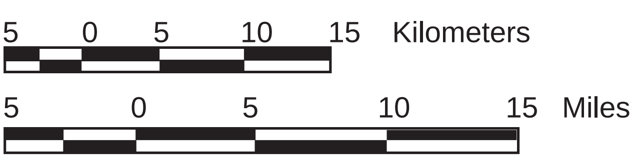
Yellow bullhead distribution in the Pocomoke basin, 1994 and 1997.



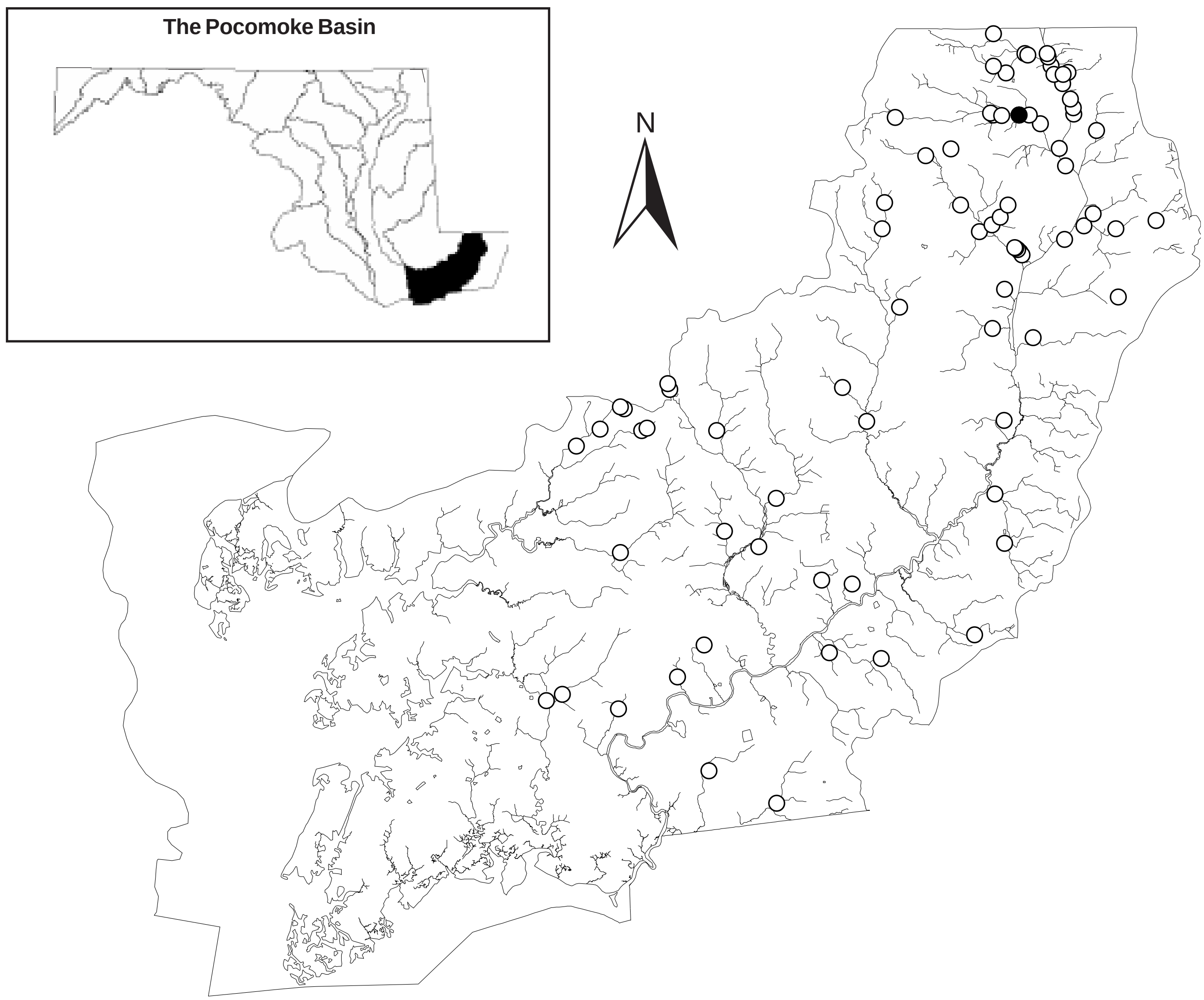
Species PRESENT at site

Species ABSENT at site



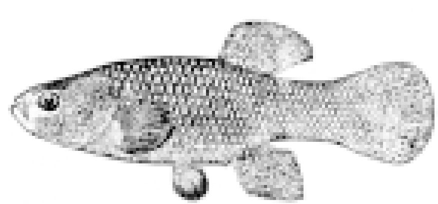


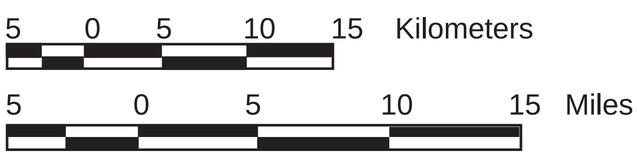
Pirate perch distribution in the Pocomoke basin, 1994 and 1997.



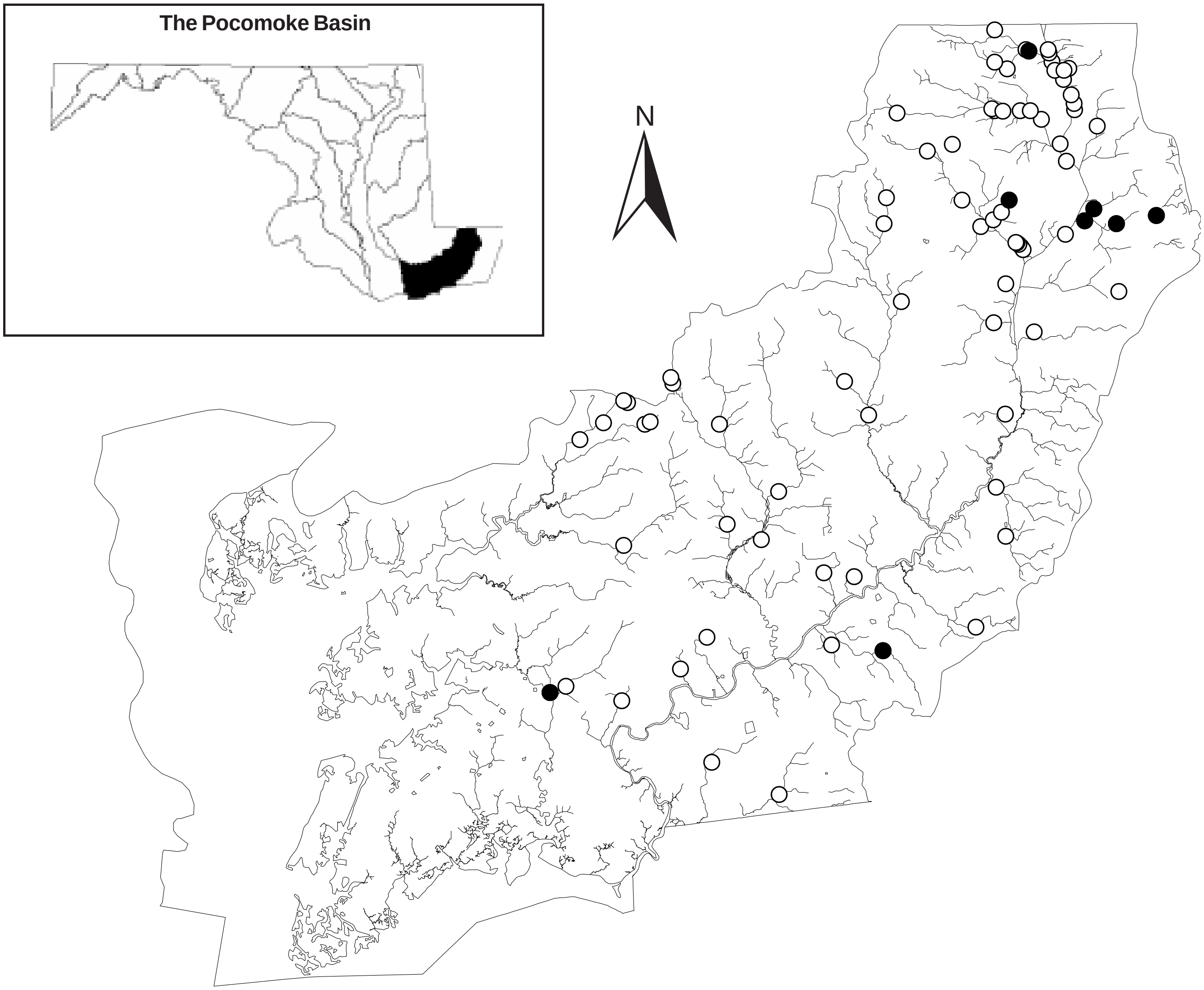
Species PRESENT at site

Species ABSENT at site



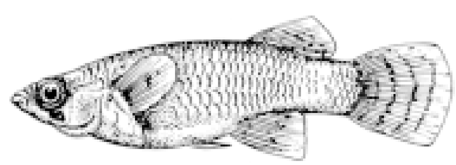


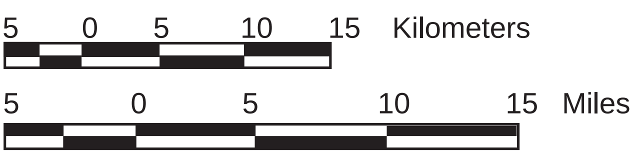
Mummichog distribution in the Pocomoke basin, 1994 and 1997.



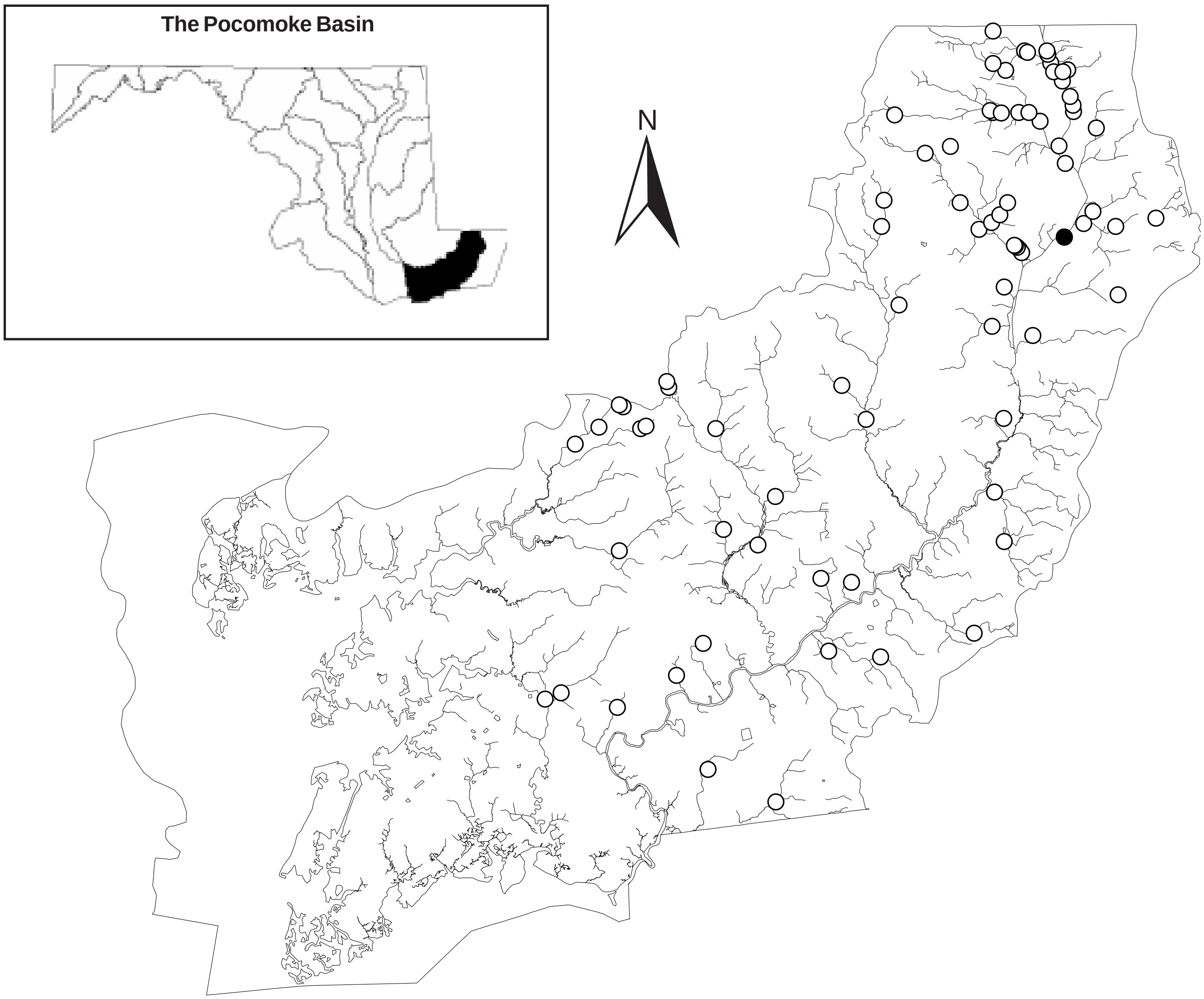
● **Species PRESENT at site**

○ **Species ABSENT at site**



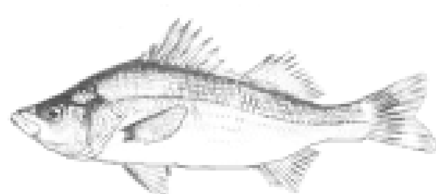


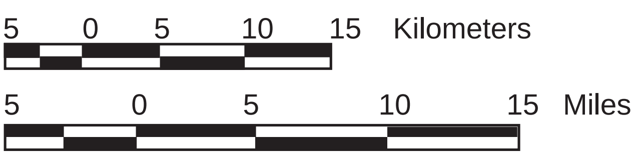
Eastern mosquitofish distribution in the Pocomoke basin, 1994 and 1997.



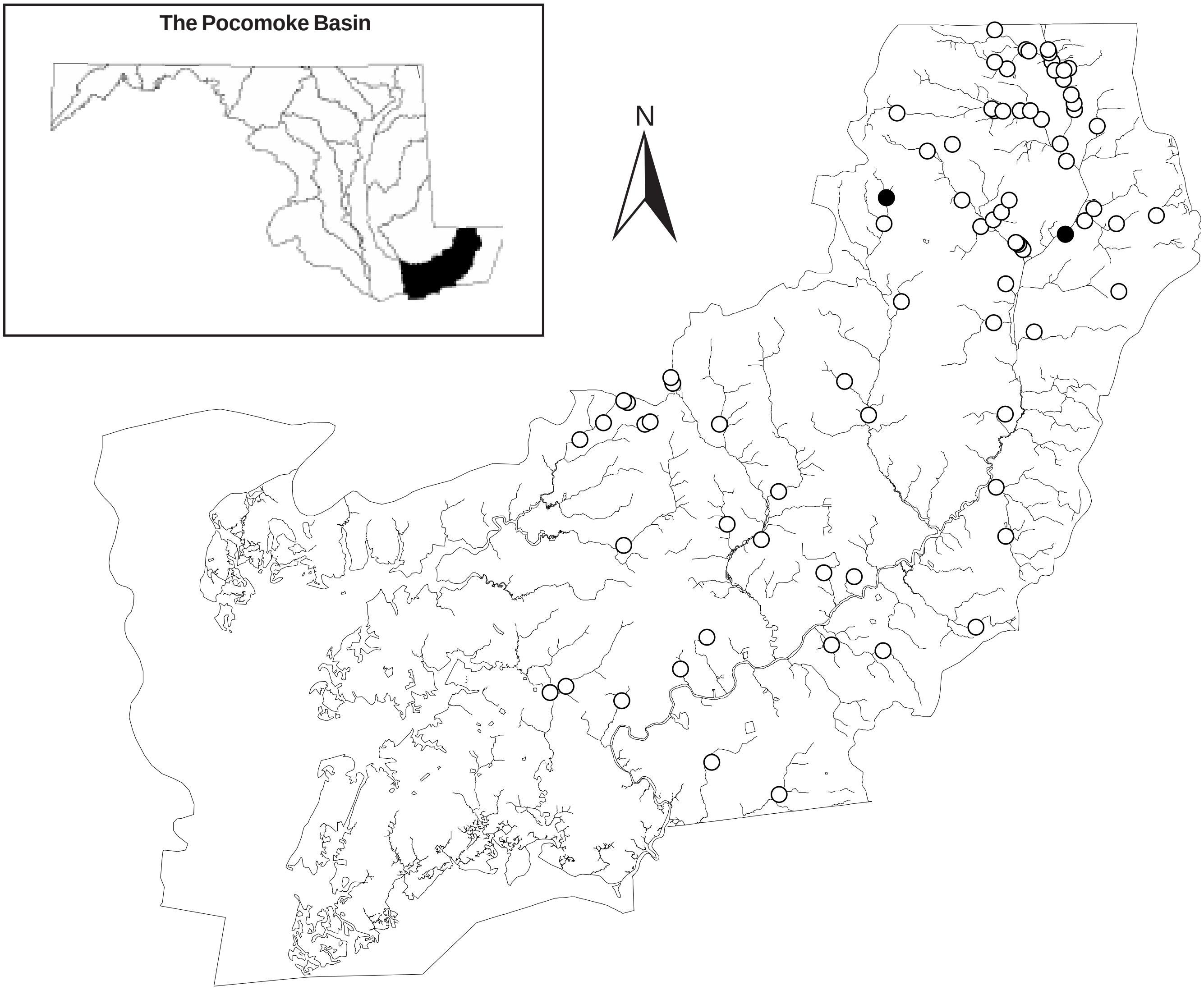
● **Species PRESENT at site**

○ **Species ABSENT at site**





White perch distribution in the Pocomoke basin, 1994 and 1997.



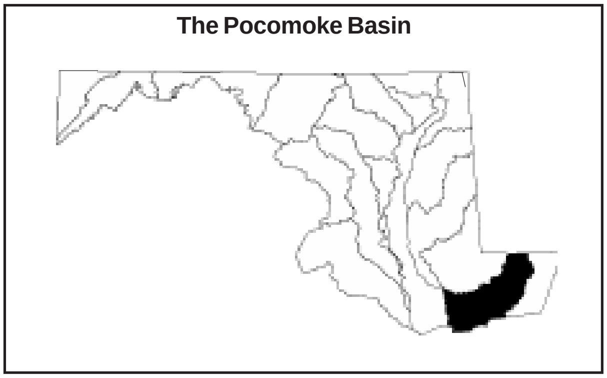
Species PRESENT at site

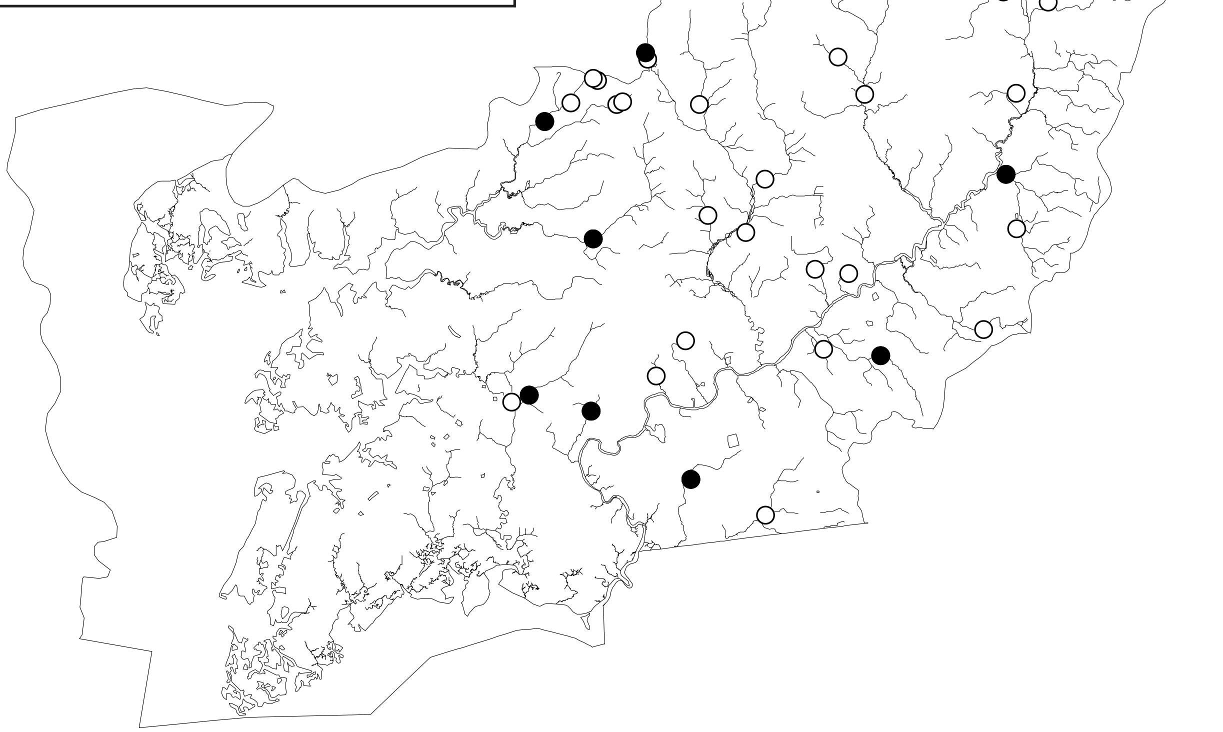
Species ABSENT at site

5 0 5 10 15 Kilometers

5 0 5 10 15 Miles

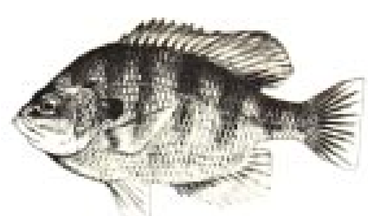
Black crappie distribution in the Pocomoke basin, 1994 and 1997.





● **Species PRESENT at site**

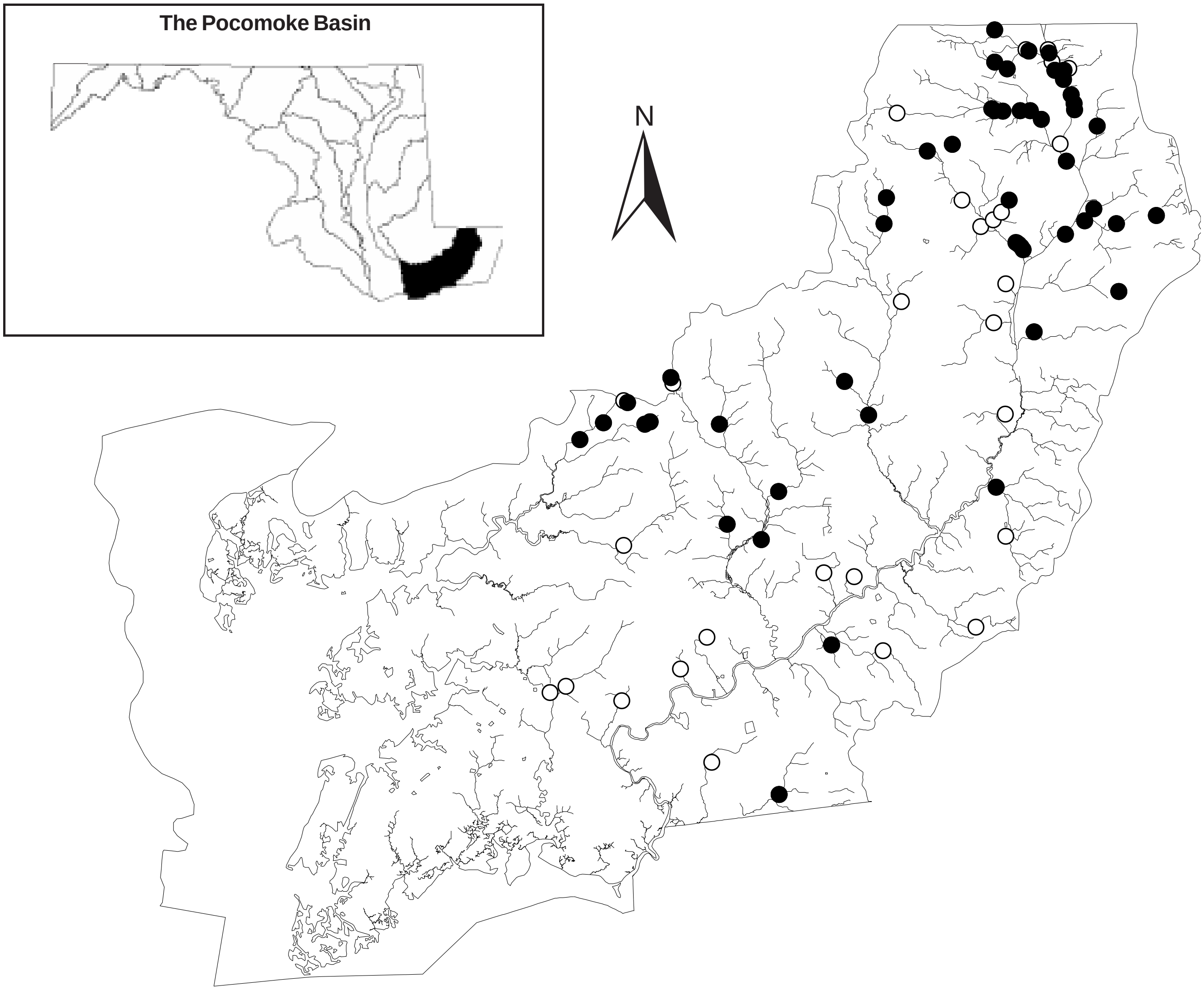
○ **Species ABSENT at site**

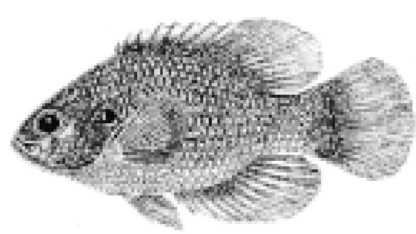


5 0 5 10 15 Kilometers

5 0 5 10 15 Miles

Bluegill distribution in the Pocomoke basin, 1994 and 1997.





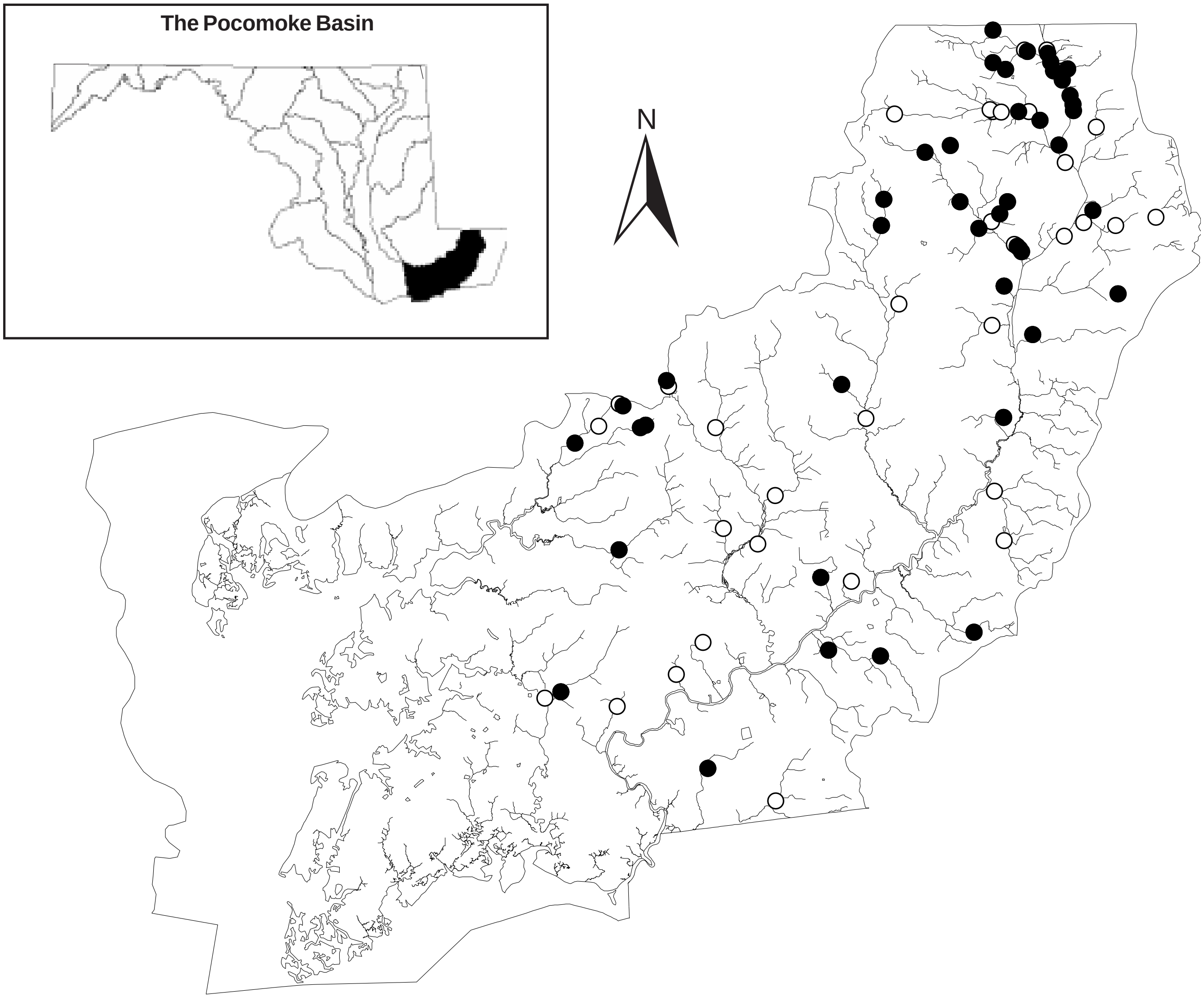
Species PRESENT at site

Species ABSENT at site

5 0 5 10 15 Kilometers

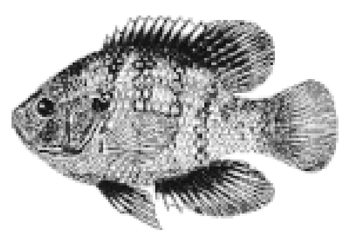
5 0 5 10 15 Miles

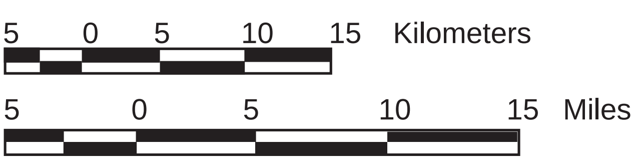
Bluespotted sunfish distribution in the Pocomoke basin, 1994 and 1997.



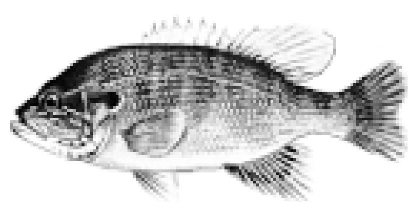
Species PRESENT at site

Species ABSENT at site





Banded sunfish distribution in the Pocomoke basin, 1994 and 1997.



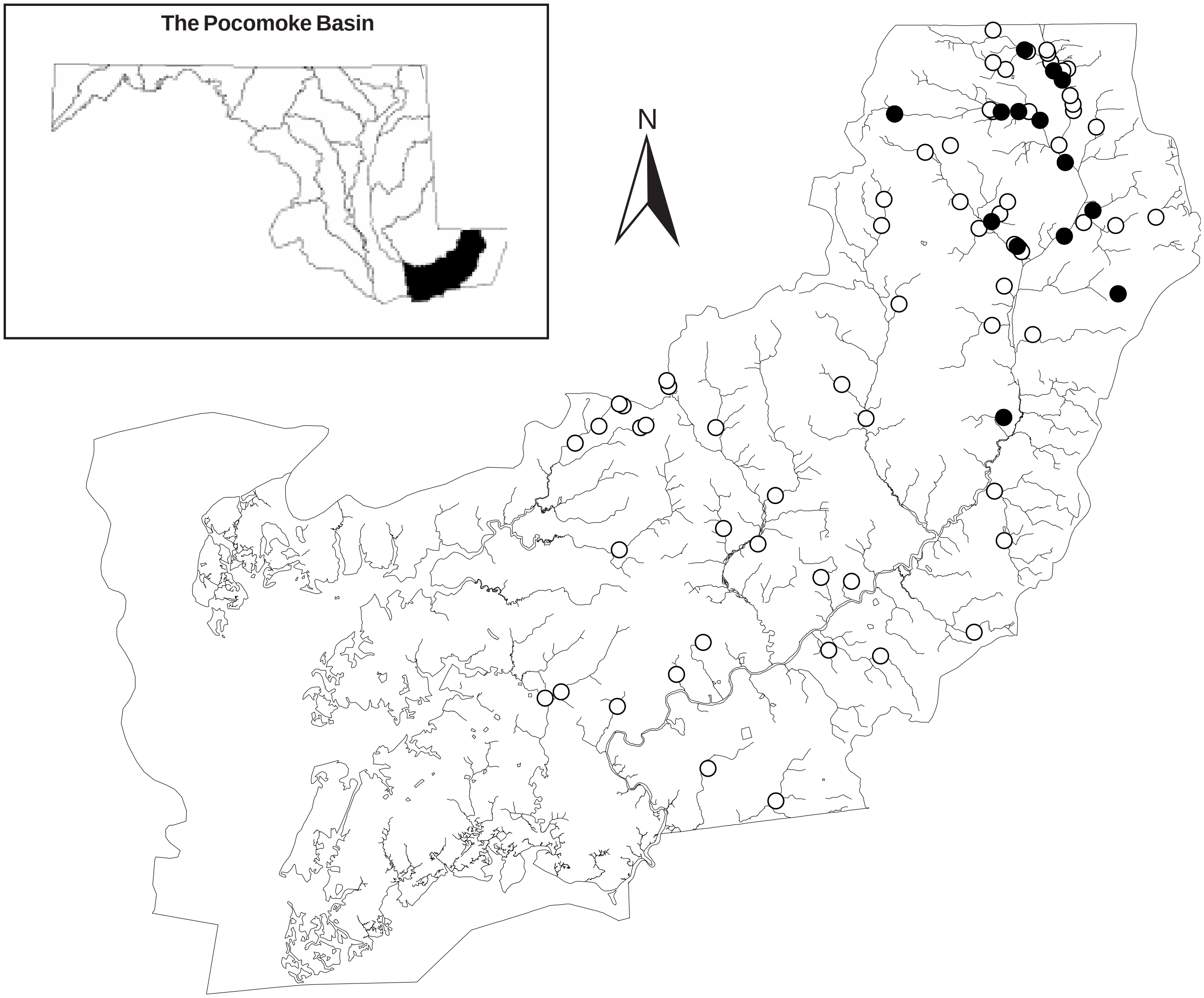
Species PRESENT at site

Species ABSENT at site

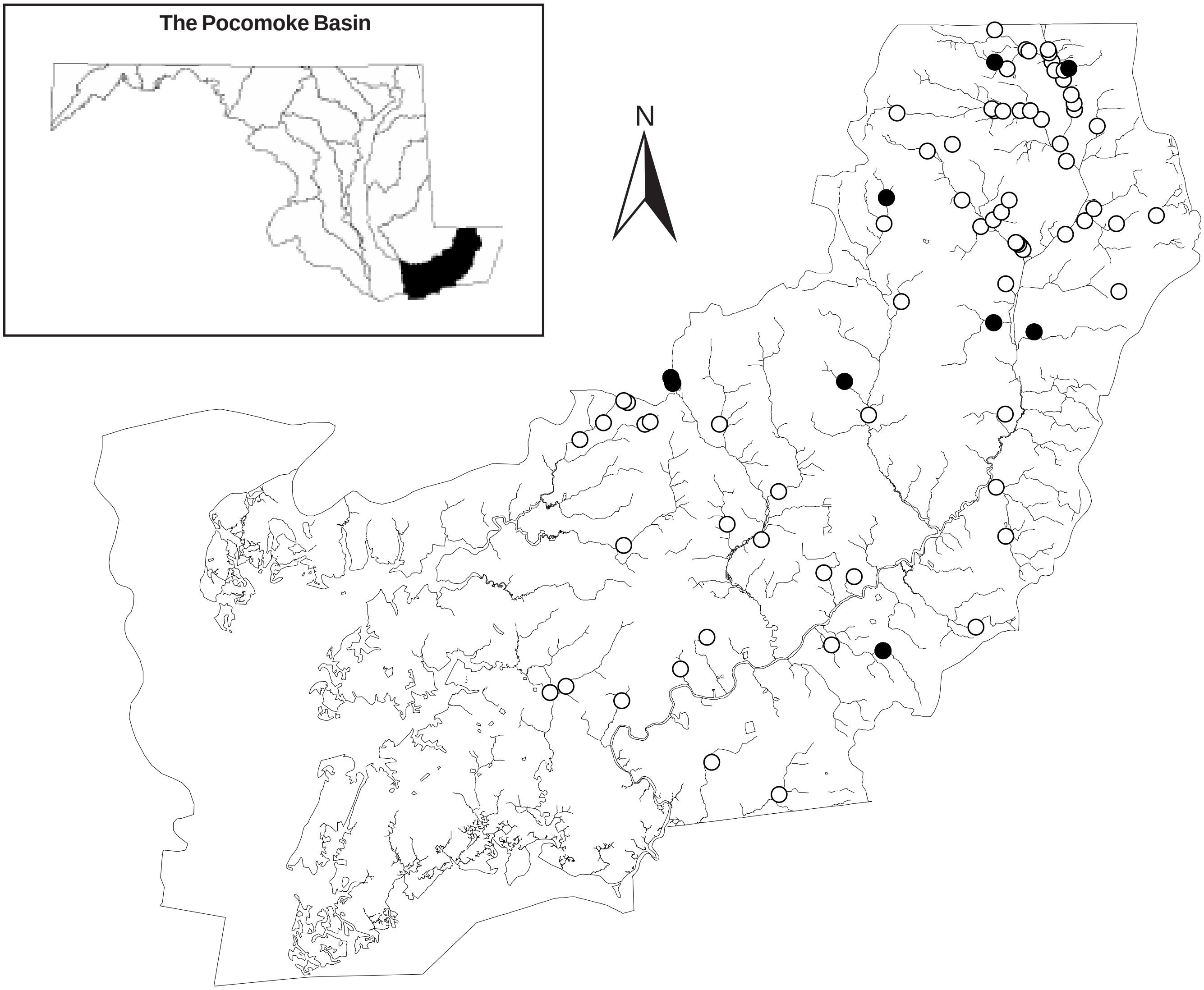
5 0 5 10 15 Kilometers

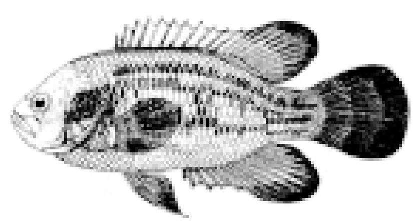
5 0 5 10 15 Miles

Green sunfish distribution in the Pocomoke basin, 1994 and 1997.



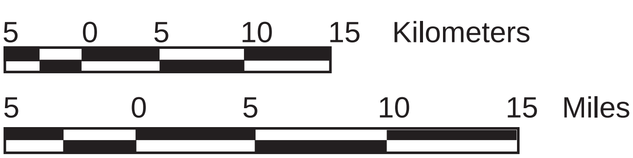
Largemouth bass distribution in the Pocomoke basin, 1994 and 1997.



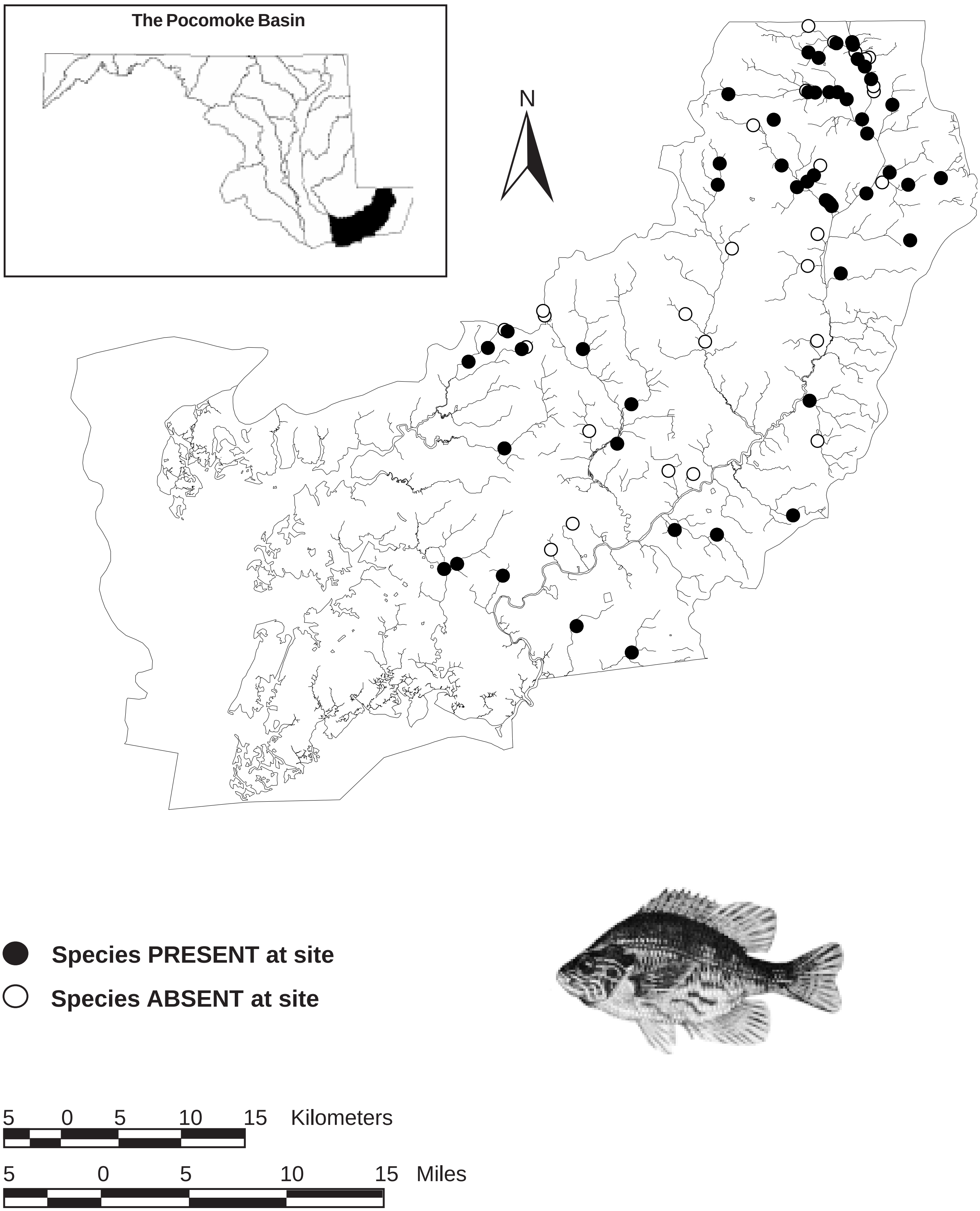


Species PRESENT at site

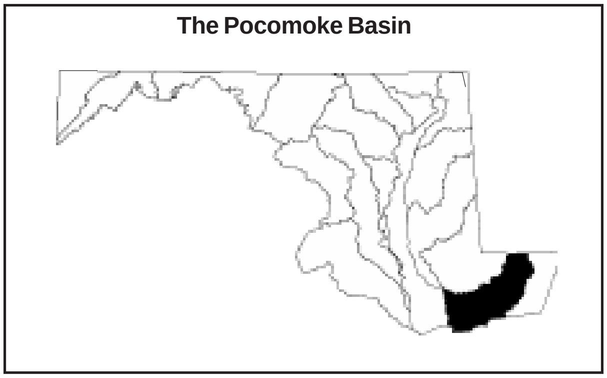
Species ABSENT at site

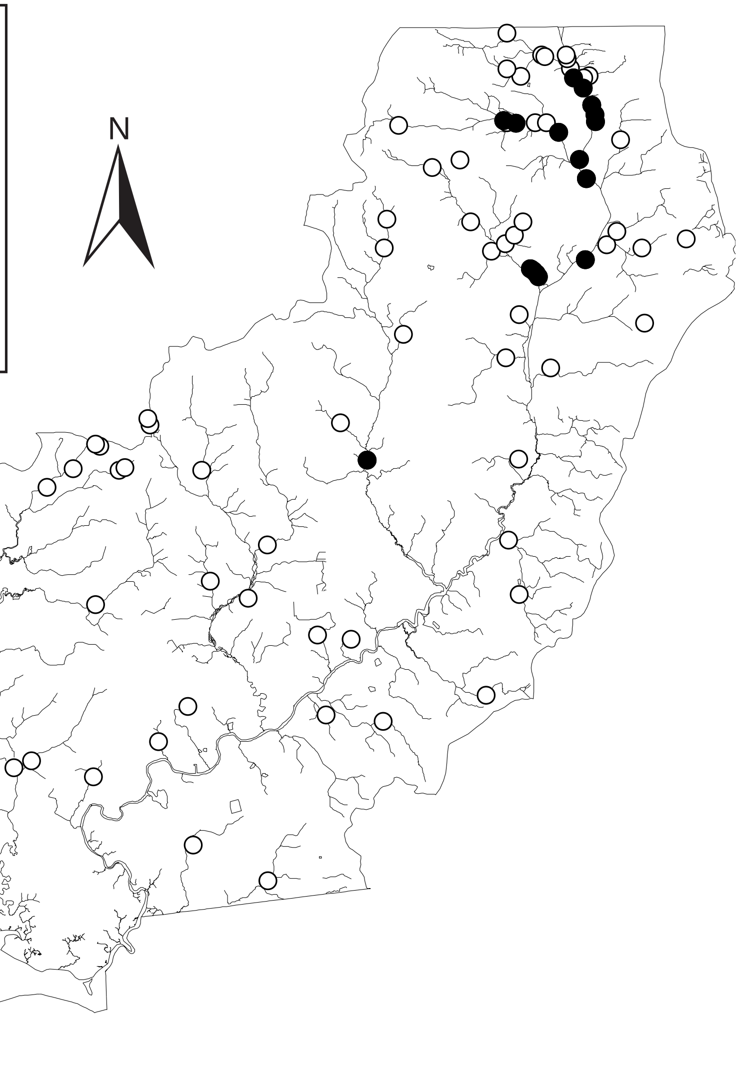


Mud sunfish distribution in the Pocomoke basin, 1994 and 1997.



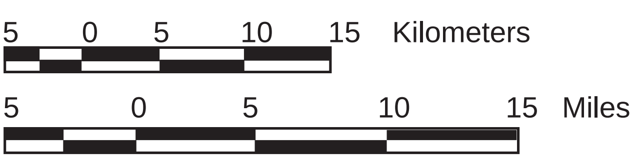
Pumpkinseed distribution in the Pocomoke basin, 1994 and 1997.



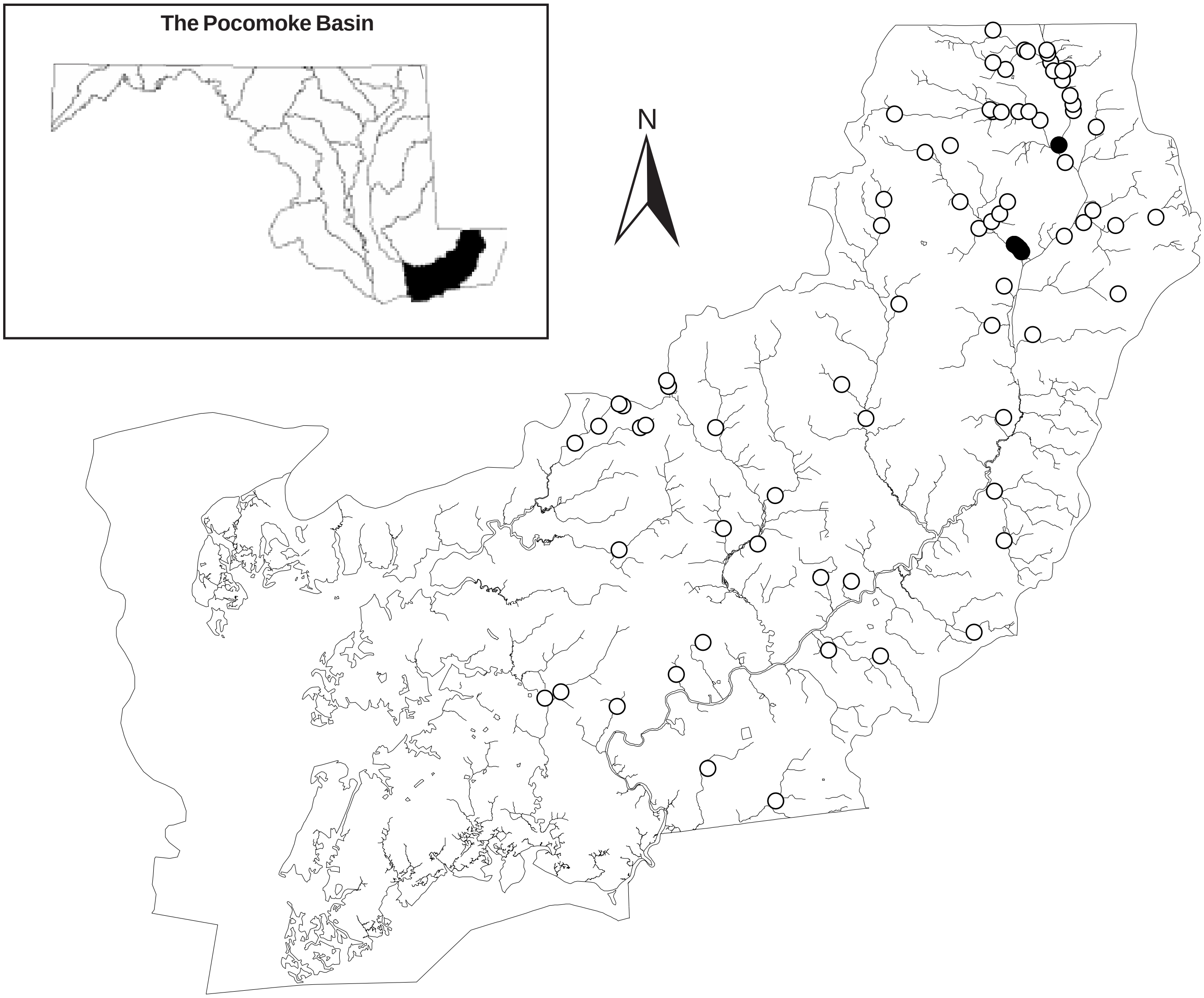


● Species PRESENT at site

○ Species ABSENT at site

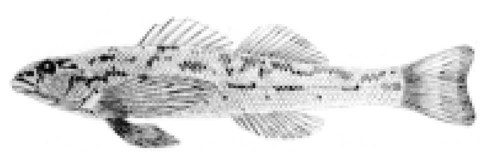


Redbreast sunfish distribution in the Pocomoke basin, 1994 and 1997.



● **Species PRESENT at site**

○ **Species ABSENT at site**



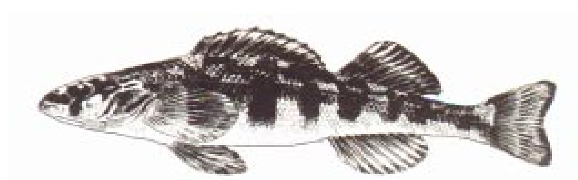
5 0 5 10 15 Kilometers

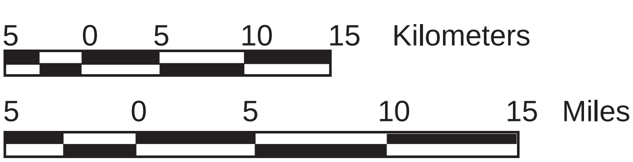
5 0 5 10 15 Miles

Glassy darter distribution in the Pocomoke basin, 1994 and 1997.

● **Species PRESENT at site**

○ **Species ABSENT at site**

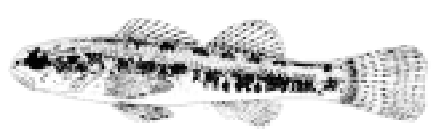




Shield darter distribution in the Pocomoke basin, 1994 and 1997.

Species PRESENT at site

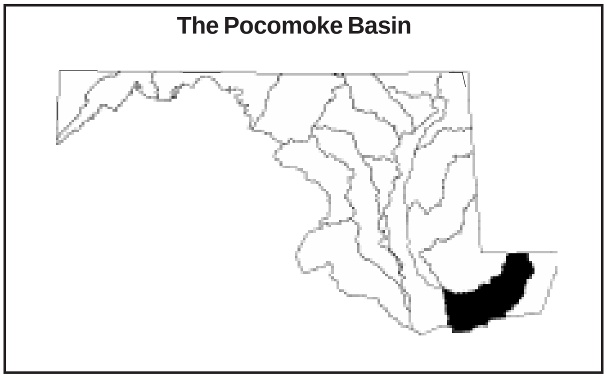
Species ABSENT at site

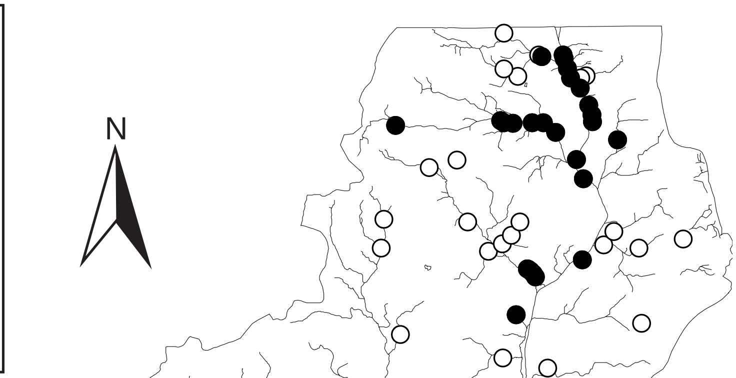


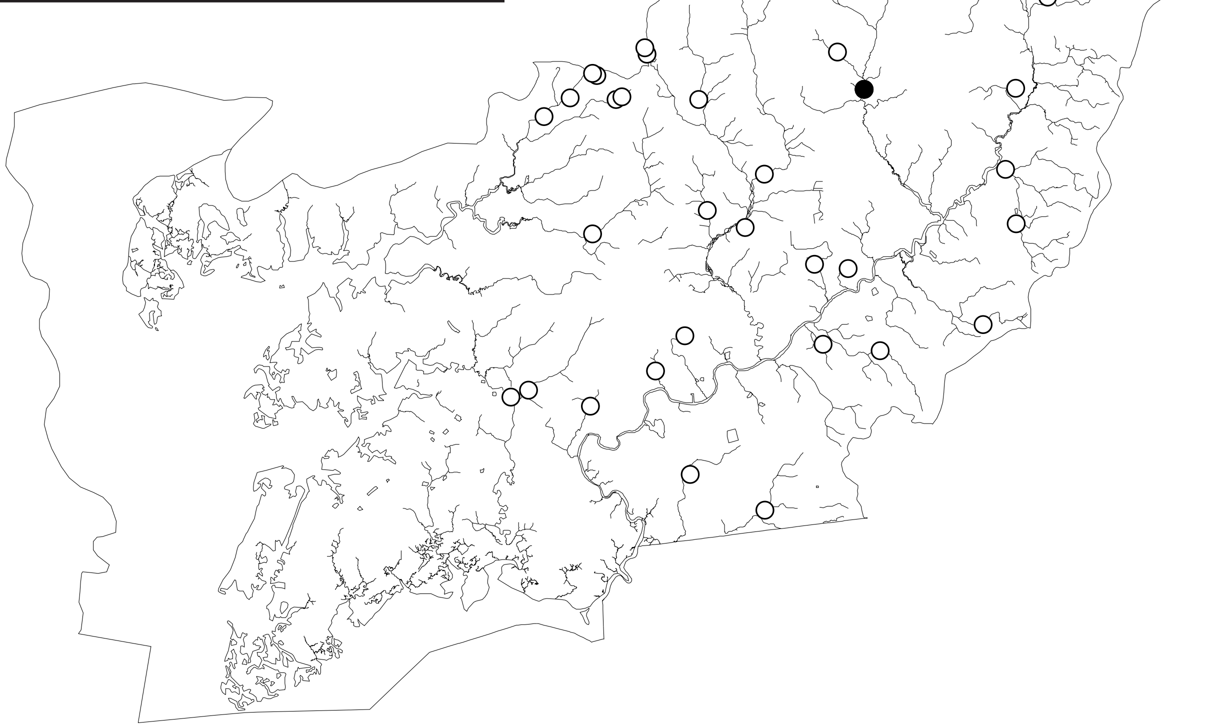
5 0 5 10 15 Kilometers

5 0 5 10 15 Miles

Swamp darter distribution in the Pocomoke basin, 1994 and 1997.

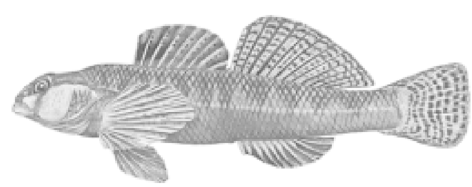






Species PRESENT at site

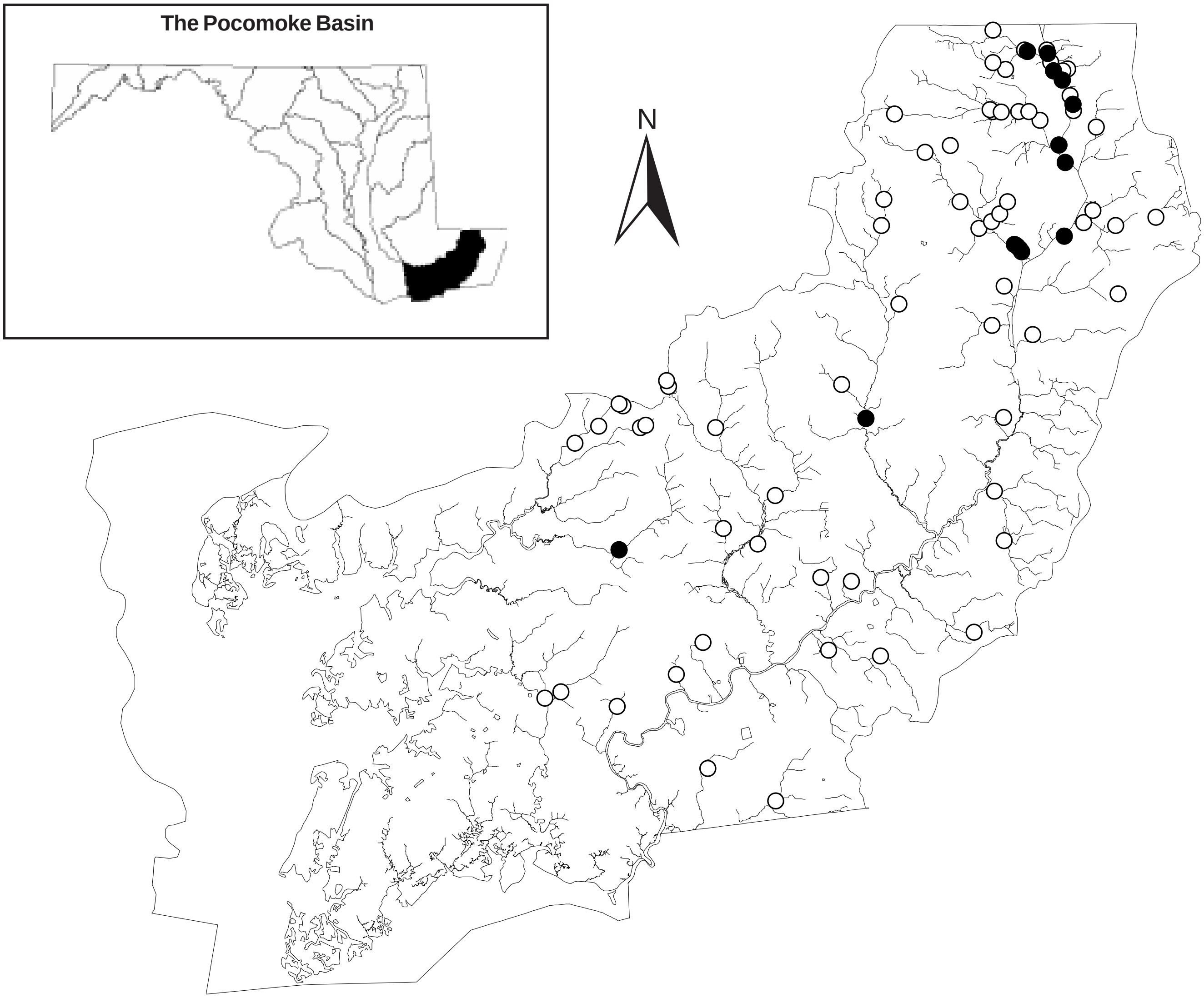
Species ABSENT at site



5 0 5 10 15 Kilometers

5 0 5 10 15 Miles

Tessellated darter distribution in the Pocomoke basin, 1994 and 1997.



● Species PRESENT at site

○ Species ABSENT at site

5 0 5 10 15 Kilometers

5 0 5 10 15 Miles

Yellow perch distribution in the Pocomoke basin, 1994 and 1997.

Appendix F. Benthic macroinvertebrate taxa with designated tolerance value (TolVal), functional feeding group (FFG), habit, and percent occurrence (% Occ.) for the 1997 MBSS sites in the Pocomoke basin. (modified from Stribling et al. 1998). Abbreviations of habits are as follows: bu - burrower, cn - clinger, sp - sprawler, cb - climber, sw - swimmer, dv - diver, sk - skater.

Class	Order	Family	Taxon	TolVal	FFG	Habit	% Occ.
Nematomorpha						bu	2.9
Enopla	Hoplonemertea	Tetrastemmatidae	*Prostoma*		Predator	Unknown	14.7
Turbellaria	Tricladida	Planariidae	*Cura*		Unknown	sp	5.9
			Dugesia	7	Predator	sp	8.8
Oligochaeta	Lumbriculida	Lumbriculidae		10	Collector	bu	29.4
	Tubificida	Enchytraeidae		10	Collector	bu	5.9
		Tubificidae	*Limnodrilus*	10	Collector	cn	5.9
		Naididae		10	Collector	bu	11.8
Gastropoda	Basommatophora	Lymnaeidae	*Pseudosuccinea*	6	Collector	cb	2.9
		Physidae	*Physella*	8	Scraper	cb	5.9
		Planorbidae	*Gyraulus*	8	Scraper	cb	2.9
			Menetus	8	Scraper	cb	5.9
	Mesogastropoda	Hydrobiidae	*Amnicola*	8	Scraper	cb	11.8
		Viviparidae	*Campeloma*	6	Scraper	cb	2.9
			Viviparus	1	Scraper	cb	2.9
Pelecypoda	Veneroida	Corbiculidae	*Corbicula*	6	Filterer	bu	2.9
		Sphaeriidae	*Pisidium*	8	Filterer	bu	23.5
			Sphaerium	8	Filterer	bu	14.7
Malacostraca	Amphipoda	Crangonyctidae	*Crangonyx*	4	Collector	sp	44.1
		Gammaridae	*Gammarus*	6	Shredder	sp	23.5
		Hyalellidae	*Hyalella*	6	Shredder	sp	2.9
	Decapoda	Cambaridae	*Cambarus*	6	Collector	sp	2.9
		Palaemonidae	*Palaemonetes*	7	Unknown	sp	23.5
	Isopoda	Asellidae	*Caecidotea*	8	Collector	sp	64.7
Insecta	Ephemeroptera	Caenidae	*Caenis*	7	Collector	sp	11.8
		Heptageniidae	*Epeorus*	0	Scraper	cn	2.9
			Stenonema	4	Scraper	cn	32.4
		Leptophlebiidae	*Leptophlebia*	4	Collector	sw, cn, sp	2.9
			Paraleptophlebia	2	Collector	sw, cn, sp	2.9
Insecta	Odonata	Calopterygidae	*Calopteryx*	6	Predator	cb	20.6
		Coenagrionidae	*Argia*	8	Predator	cn, cb, sp	2.9
			Enallagma	8	Predator	cb	2.9
		Corduliidae	*Somatochlora*	1	Predator	sp	2.9
		Gomphidae	*Gomphus*	5	Predator	bu	2.9
			Lanthus	6	Predator	bu	2.9
Insecta	Plecoptera	Nemouridae	*Ostrocerca*		Shredder	sp, cn	2.9
			Prostoia		Shredder	sp, cn	14.7
		Taeniopterygidae	*Taeniopteryx*	2	Shredder	sp, cn	5.9
Insecta	Hemiptera	Belostomatidae	*Belostoma*	10	Predator	cb, sw	2.9
Insecta	Trichoptera	Dipseudopsidae	*Phylocentropus*	5	Collector	bu	5.9
		Hydropsychidae	*Cheumatopsyche*	5	Filterer	cn	23.5
			Hydropsyche	6	Filterer	cn	2.9
		Hydroptilidae	*Oxyethira*	3	Collector	cb	2.9
		Leptoceridae	*Oecetis*	8	Predator	cn, sp, cb	17.6
			Triaenodes	6	Shredder	sw, cb	8.8
		Limnephilidae	*Ironoquia*	3	Shredder	sp	23.5
			Pycnopsyche	4	Shredder	sp, cb, cn	23.5

Class	Order	Family	Taxon	TolVal	FFG	Habit	% Occ.
		Polycentropodidae	*Polycentropus*	5	Filterer	cn	44.1
		Psychomyiidae	*Lype*	2	Scraper	cn	20.6
Insecta	Lepidoptera	Pyralidae			Shredder	cb	5.9
Insecta	Coleoptera	Dytiscidae	*Agabus*	5	Predator	sw, dv	2.9
			Hydroporus	5	Predator	sw, cb	14.7
		Elmidae	*Ancyronyx*	2	Scraper	cn, sp	20.6
			Dubiraphia	6	Scraper	cn, cb	32.4
			Macronychus	4	Scraper	cn	2.9
		Gyrinidae	*Stenelmis*	6	Scraper	cn	2.9
			Dineutus	4	Predator	sw, dv	20.6
		Haliplidae	*Gyrinus*	4	Predator	sw, dv	11.8
		Hydrophilidae	*Peltodytes*	5	Shredder	cb, cn	8.8
			Enochrus	5	Collector	bu, sp	2.9
Insecta	Diptera	Ceratopogonidae	*Tropisternus*	10	Collector	cb	2.9
			Alluaudomyia		Predator	bu	2.9
			Bezzia	6	Predator	bu	2.9
			Sphaeromias		Predator	bu	2.9
		Chironomidae	*Ablabesymia*	8	Predator	sp	23.5
			Brillia	5	Shredder	bu, sp	14.7
			Chironomus	10	Collector	bu	2.9
			Clinotanypus	8	Predator	bu	11.8
			Conchapelopia	6	Predator	sp	76.5
			Corynoneura	7	Collector	sp	17.6
			Cricotopus	7	Shredder	cn, bu	20.6
			Cricotopus/Orthocladius		Shredder	Unknown	50.0
			Dicrotendipes	10	Collector	bu	29.4
			Endochironomus	10	Shredder	cn	14.7
			Eukiefferiella	8	Collector	sp	5.9
			Hydrobaenus	8	Scraper	sp	5.9
			Labrundinia	7	Predator	sp	5.9
			Micropsectra	7	Collector	cb, sp	11.8
			Nanocladius	3	Collector	sp	14.7
			Nilotanypus	6	Predator	sp	2.9
		Orthocladiinae A		6	Collector	sp, bu	14.7
		Orthocladiinae B		6	Collector	sp, bu	2.9
			Orthocladius	6	Collector	sp, bu	5.9
			Paralauterborniella	8	Collector	cn	2.9
			Paratanytarsus	6	Collector	sp	20.6
			Phaenopsectra	7	Collector	cn	29.4
			Polypedilum	6	Shredder	cb, cn	70.6
			Procladius	9	Predator	sp	11.8
			Psectrocladius	8	Shredder	sp, bu	5.9
			Rheocricotopus	6	Collector	sp	41.2
			Rheotanytarsus	6	Filterer	cn	50.0
			Stenochironomus	5	Shredder	bu	5.9
			Stictochironomus	9	Collector	bu	2.9
			Symposiocladius		Predator	sp	2.9
			Tanytarsus	6	Filterer	cb, cn	23.5
			Thienemanniella	6	Collector	sp	17.6
			Thienemannimyia		Predator	sp	5.9
			Tribelos	5	Collector	bu	14.7

Class	Order	Family	Taxon	TolVal	FFG	Habit	% Occ.
			Tvetenia	5	Collector	sp	5.9
			Xylotopus	2	Shredder	bu	2.9
			Zavrelimyia	8	Predator	sp	14.7
		Empididae	*Hemerodromia*	6	Predator	sp, bu	26.5
		Simuliidae	*Cnephia*	4	Filterer	cn	8.8
			Prosimulium	7	Filterer	cn	11.8
			Simulium	7	Filterer	cn	35.3
			Stegopterna	7	Filterer	cn	50.0
		Tabanidae	*Chrysops*	7	Predator	sp, bu	2.9
		Tipulidae	*Pilaria*	7	Predator	bu	2.9